International

WOCE

Newsletter

Number 17 November 1994

IN THIS ISSUE

Published by WOCE International Project Office at NERC IOS Deacon Laboratory, Wormley, UK

Planning for the future of WOCE

W. John Gould, Director, WOCE IPO

Since our last Newsletter, which was a bumper issue, WOCE has started to consider the strategy that it will adopt for the later phases of the project.

WOCE went through a long planning process for the implementation of the observational phase and it is gratifying to see that we are on target to complete almost all of the Global One-Time survey. Planning for the Atlantic is underway both in the USA, and internationally under the auspices of CP3. Bids for funding and for ship time for the 1996–97 Atlantic observations will soon have to be submitted.

The analysis and synthesis of WOCE data similarly needs to be planned to ensure that we make the best use of the data collected, that we have a realistic estimate of the time scale to which we should work to complete the analysis and synthesis and that we develop the means to demonstrate the achievements of WOCE. The WOCE SSG at its meeting in Kiel in October, agreed to produce a strategy for the synthesis phase and this will be presented to our parent organisation, the Joint Scientific Committee of the World Climate Research Programme, in March 1995. This strategy will be widely publicised and may then be used by countries to approach their funding agencies in order to support the analysis of WOCE data after 1997.

The WOCE committee structure that was appropriate for planning and implemementation of the observations is not ideal for the tasks that WOCE will have to carry out beyond 1997 and therefore there will be changes. The SSG will, over time, shrink to a small executive. The main scientific oversight committee will be a Synthesis and Modelling Working Group (SMWG) that will replace the Numerical Experimentation Group and the Core Project 1 and 2 Groups. Its formation brings together both observationalists and modellers who will have to address the complex issues of data synthesis and assimilation. The WOCE Hydrographic Programme Planning Committee is seen to be needed for oversight of observations to 1997 and of the WHP Data Assembly and Special Analysis Centres (DACs and SACs) and of WHP data flow beyond that time. CP3 will exist until the Atlantic programme is well underway.

CLIVAR (see Newsletter 16) is in some ways a natural successor to WOCE and two committees, the Surface Velocity Panel and the XBT/XCTD Programme Committee, which were co-sponsored by WOCE and TOGA will become WOCE/CLIVAR committees. The Data Assembly Centres and Special Analysis Centres established by WOCE will have an important role to play in WOCE for a considerable time. The extent to which these structures may be used by other observational programmes such as CLIVAR has yet to be assessed. Most other WOCE planning committees will cease to exist from the end of 1994 but we have taken steps to ensure that all subject areas of importance to WOCE will be represented on the SMWG.

I would like to take this opportunity to thank all the scientists who have given their time to help on these committees in the planning and implementation of WOCE. It often seems a thankless task, but the reward is to see WOCE taking shape and achieving its objectives.

I had hoped that in this Newsletter I would be able to report on the Intergovernmental WOCE Panel meeting that was planned for October. Unfortunately we had to postpone the meeting at rather short notice. The WOCE SSG however agreed to hold IWP-3 in June 1995 in conjunction with the IOC Assembly. This will be an important opportunity to convey to national representatives the achievements of WOCE and to explain to them WOCE's plans for the future.

Our Newsletter has a new Editor, Andrea Frische, who is now firmly established in Wormley. She will be pressing you to submit your latest results to the International WOCE Newsletter. Our mailing list currently stands at 1200 and each issue is widely read so it is a good means of quickly telling the science community what you've discovered.

In this issue you will see a number of articles concerning the South Atlantic. This has been an area of intense study early in WOCE and it is gratifying to see that new results are starting to emerge. One article by Mercier and Bryden is a follow up to an article in Newsletter 16. That is the way a newsletter should work and we encourage it. The North Atlantic analysis will benefit from comparisons with model results and we have in this issue an article on the first runs of an eddy-resolving isopycnic code model (AIM).

Time series stations were part of WOCE planning but have been undersubscribed. However the stations that do exist are extremely valuable and we present information on two of them; in the Pacific and near the Canary Islands. In a newsletter space is limited and the article by Pierre Rual on the XBT fall rate has had to be greatly shortened – however we hope it conveys the essential elements of what has been a substantial and important study.

Our next issue in the spring of 1995 plans to focus on the Southern Ocean and you are encouraged to submit candidate articles by mid February at the latest. Preferably ASCII text should be sent by e-mail to woceipo@unixa.nerc-wormley.ac.uk with figures by airmail or in postscript files.

In the meantime we in the WOCE IPO send you our best wishes for 1995.

Status of the Deep Basin Experiment

Nelson Hogg, Woods Hole Oceanographic Institution, MA 02543, USA

Experiment Design

Under the auspices of the WOCE Core Project 3 a large international programme has been focused on the deep circulation of the Brazil Basin. This involves scientists from Brazil, France, Germany and the US in a cooperative exploration of the three-dimensional flow of the various water masses with a special emphasis on the Antarctic Intermediate Water (AAIW), the North Atlantic Deep Water (NADW) and the Antarctic Bottom Water (AABW). The programme has four main objectives:

(1) to observe and quantify the deep circulation within an abyssal basin;

(2) to distinguish between boundary and internal mixing processes;

(3) to understand how passages affect the water flowing through them; and

(4) to study the means by which deep water crosses the equator.

The Brazil Basin was chosen as the site of this experiment because of its relatively simple geometry and the fact that it exists in a region of expected low eddy kinetic energy, an important attribute in designing a programme aimed at the "mean" circulation.

At this writing the field work is still underway but some data has been returned and some of this was discussed at the recent "South Atlantic Symposium" in Bremen, Germany. Those DBE participants present at the symposium also took the opportunity to discuss the programme. A summary of this discussion and the status of the DBE is the subject of this note.

The field programme is a combination of conventional hydrography done at WOCE standards (so as to include the standard Core 1 tracer suite on most lines), direct velocity measurements using current meters and neutrally buoyant floats and a deliberate tracer release (Figure 1). The hydrographic lines (dashed lines in Fig. 1) are virtually complete and were designed to subdivide the basin into a number of smaller boxes with the expectation being that this would permit the spatial resolution of cross isopycnal processes and allow some discrimination between boundary and interior regimes.

Four of the five current meter arrays have been set across the major passages which connect the Brazil Basin to the neighbouring basins. All have been deployed for approximately two year exposures and all but the Romanche/Chain array (on the equator near 15°W) have been recovered. The fifth array is near 19°S at the midbasin point and is scheduled for recovery in March 1995.

Perhaps the most ambitious component is the neutrally buoyant float programme. In this, a combination of German, French and US investigators will release from 75 to 150 floats in each of the three principal water masses of the subthermocline region. These floats are variants of the "RAFOS" design and will listen for signals transmitted by the array of sound sources shown on Figure 1 (solid circles) for periods up to 5 years. Most of these floats will have been deployed by the end of 1995.

A final component of the field programme is a deliberate tracer release styled after the North Atlantic Tracer Release Experiment (NATRE) but here focused on the deep water. Details of the release are still evolving but it will most likely be done at two locations near 4000 m: one in the interior and another near a boundary (western or eastern). Logistics (*i.e.* expense) could force the experiment to occur in the North Atlantic.

Some Results

As mentioned above, the most complete aspect of the DBE is the hydrographic survey. This data is still being edited and calibrated but sections of water properties and tracers were shown at the Bremen meeting. The southern boundary of the Basin was attacked early on and several manuscripts have been produced concerning this region. The total exchange of bottom water from the Argentine Basin appears to be about 7 Sv with 4 entering through the Vema Channel, 2 over the Santos Plateau and less than 1 through the Hunter Channel to the east (Speer and Zenk, 1993; Speer *et al*., 1992). These estimates will be refined when direct velocity measurements are incorporated. It also appears that the bottom water is warming where it enters the Brazil Basin (Zenk and Hogg, in preparation).

Estimates of the rate at which AABW leaves the Basin into the North Atlantic have ranged from less than 1 Sv (Whitehead and Worthington, 1982) to more than 4 Sv (McCartney, 1995). Preliminary estimates from a recently recovered array across an equatorial passage split the difference and give about 2 Sv (Hall, Whitehead and McCartney - see article in this newsletter). The other exit for AABW is the Romanche-Chain Fracture Zone but estimates for this must await recovery of that array later this year. It is unlikely that this transport will be as much as 3 Sv meaning that some significant amount of bottom water must upwell within the Basin.

The float programme is still in its infancy but enough trajectories have been returned to paint a new and provocative picture of the circulation of North Atlantic Deep Water, one that is more zonal than meridional within the Brazil Basin, at odds with both the Stommel and Arons (1960) and Reid (1989) schemes. On the other hand, float measurements within the Antarctic Intermediate Water support the available schemes showing westward flow toward the coast near 30°S which then diverges toward the north and south near the boundary.

Meeting report

A brief meeting of DBE participants was held at the Bremen meeting. Discussion centred on several matters related to data exchange and future analysis activities. The official WOCE policy states that hydrographic data will be made available 2 years after collection and time dependent tracer data is to be available 2 years after chemical analysis. There is some pressure from the freon community to give an additional 2 year grace period to these tracers during which data would be made available only with the consent of the person who was responsible for it. Current meter and float data policy is vague although there does exist a US policy that it should be made available on the same schedule as hydrographic data. For floats this presumably means 2 years after the last float has surfaced and returned its data. These issues are not specific to the DBE community but it is clear that the objectives of programmes such as the DBE do rely on fairly prompt and free exchange of information.

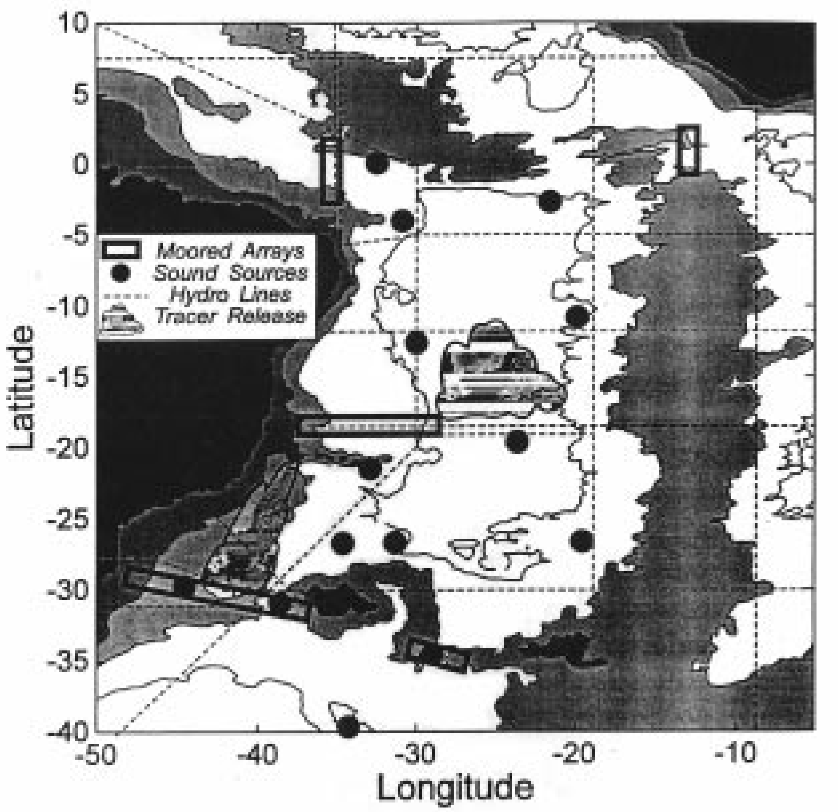

Figure 1. Location of the DBE field programme.

Beyond the workup and analysis of individual data sets we must start planning toward the synthesis of all the data. Some plans were discussed and these include:

(a) Weatherly: Followup on work recent work with du Madron to clarify deep circulation in Brazil Basin, probably using classical methods.
(b) Kiel group: Heat flux at southern boundary, circulation of AAIW, and study of boundary currents off Brazil (with Brazilians).
(c) Brest group: There will be a unified French approach most likely involving inverse models using sections which make closed boxes.
(d) WHOI: AABW and NADW heat and mass balances (Whitehead). Circulation schemes from array data with hydrography (McCartney). Inversion of whole data set to look at diapycnal processes (Hogg and Owens).
(e) Kawase: theoretical issues that relate to the deep circulation including the dynamics of large scale circulation, sill flows, near equatorial physics and long term time dependence.

Summary

The DBE is presently at midlife and healthy. The field programmes, with the exception of the neutrally buoyant floats and the tracer release, are almost complete. There is an ever accumulating amount of new information that can now be applied to the 4 objectives. The level of cooperation between the various countries and groups has been remarkably high; ships, instruments and facilities have been freely shared. In the analysis phase upon which we are now embarking it is anticipated that this team spirit will extend to information and ideas.

References

McCartney, M.S., 1995. The transport of Antarctic Bottom Water at 4°N in the western basin of the North Atlantic Ocean. J. Geophys. Res. (accepted)

Reid, J.L., 1989. On the total geostrophic circulation of the South Atlantic Ocean: flow patterns, tracers and transports. Prog. Oceanogr., 23, 149–244.

Speer, K.G., and W. Zenk, 1993. The flow of Antarctic Bottom Water onto the Brazil Basin. J. Phys. Oceanogr., 23, 2667–2682.

Speer, K.G., W. Zenk, G. Siedler, J. Pätzold and C. Heidland, 1992. First resolution of flow through the Hunter Channel in the South Atlantic. Earth Planetary Sci. Let., 113, 287–292.

Stommel, H., and A.B. Arons, 1960. On the abyssal circulation of the World Ocean, Parts I and II. Deep-Sea Res., 6, 140–154 and 217–233.

Whitehead, J.A., and L.V. Worthington, 1982. The flux and mixing rates of Antarctic Bottom Water within the North Atlantic. J. Geophys. Res., 87, 7903–7924.

Moored Measurements of Antarctic Bottom Water at the Equator

M.M. Hall, J.A. Whitehead, and M.S. McCartney, Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA.

Antarctic Bottom Water (hereafter, AABW) lies below roughly 4000 metres depth in the western Atlantic Ocean, and is therefore highly constrained by topography as it flows from one deep basin to the next. Near the equator, it flows through a tortuous interconnecting passageway from the Brazil Basin in the western South Atlantic to the Guiana Basin in the tropical western North Atlantic. This topography forces the water to flow westward through an east-west trending gap that spans the Equator (Figure 1). The gap is approximately 230 km wide, and is bounded to the north by extensions of St. Paul's Fracture Zone, and to the south by the Parnaiba Ridge extending from the South American continent. Previous estimates of the magnitude of cross-equatorial flux of AABW range from approximately 1 to 4 Sv. For example, McCartney and Curry (1993) have made a geostrophic estimate of the volume flux of the AABW through this gap of 4.3 Sv. Rhein *et al*. (1994) measured the velocity distribution in this gap at three times with current profilers, and found, in addition to considerable variability, that the westward flowing bottom water current is greatest near the southern end of the gap, with an estimated transport of 2.6 Sv. They also observed a strong core, or jet, of eastward flowing North Atlantic Deep Water (NADW), centred at about 3800 m, between roughly 1° and 2°S.

In order to provide an accurate estimate of AABW transport (westward) out of the Brazil Basin at this location, as part of the WOCE Deep Basin Experiment, an array of six moorings with a total of 24 instruments was deployed from the RV Iselin, between 28 September and 2 October 1992. Moorings were deployed approximately every 30 minutes of latitude between 1°N and 1.5°S, along 36°W (see Figure 1). These locations not only filled the gap evenly from north to south, but also put the array at approximately the east-west centre of the almost perfectly zonal gap. All six moorings had at least three instruments (vector averaging current meters (VACM) with temperature sensors) at depths of 3900, 4100, and 4300 m. One mooring was placed almost exactly on the equator and had additional current meters at shallower levels of 3600, 3300 and 3000 m, and deeper, at 4450 m. These, as well as additional instruments at 3300 m on the moorings at 1°N

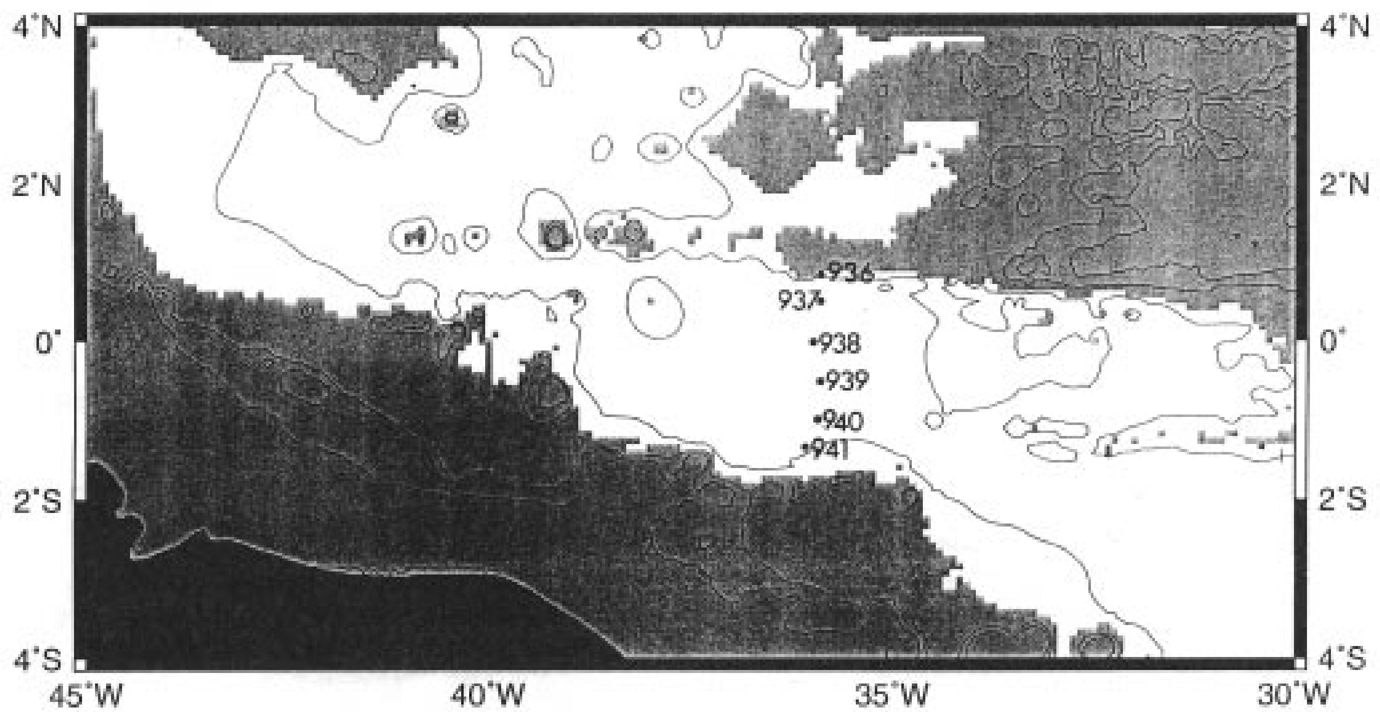

Figure 1. Local topography in the vicinity of the moored array, with mooring positions designated as dots. The shaded area is depths less than 4000 m, with the 3000 and 3500 m contours superposed. In the unshaded area, the 4250 m contour is shown. Water depth in the vicinity of the array just exceeds 4500 m at some locations.

and S, are intended to supply information about the levels of no motion. The recovery cruise took place aboard the RV Knorr, from 27 May to 13 June 1994. Data return from the roughly 610 day deployment was 98%, and a preliminary calculation for the mean AABW transport through the array yielded an estimate of 2.1 Sv. To supplement the velocity and temperature data from the moorings, 11 CTD stations were taken during both the deployment and recovery cruises, with stations located both at and between the mooring locations. Figure 2 displays potential temperature, salinity, and σ_4 (potential density referenced to 4000 dbar), from 1994, for depths below 3600 dbar, with dots representing the positions of the VACMs. So far these data have been used only to aid in calculating time series of potential temperature from the temperatures recorded by the VACMs.

Several striking qualitative features of the moored data are worth noting. First, the time series of velocities confirms Rhein *et al.*'s results, that the AABW flow is concentrated in the southern portion of the channel. To illustrate this, Figures 3 and 4 show the vector velocity time series for the northernmost and southernmost moorings, respectively. At 1°N (Figure 3), although flow at 4300 m is weakly westward in the mean, maximum velocities rarely exceed magnitudes of 5 cm s^{-1}. In contrast, at 1.5°S (Figure 4), zonal velocity is almost always westward, with a mean of -4.9 cm s^{-1}, and maximum westward velocities of 18.6 cm s^{-1}. The data also demonstrate that eastward flow of lower North Atlantic Deep Water (NADW) occurs in a narrow jet evidently confined between the equator and 1°S. This flow is seen at 3900 m in Figure 4; vector velocities at mooring 940 (not shown; near 1°S) have a similar vertical structure (though westward flow at 4300 m there is less intense), while those at 939 (~0.5°S) are strongly westward at all depths. Figure 5 shows velocities for the 7 instruments on the equatorial mooring 938 (3000, 3300, 3600, 3900, 4100,

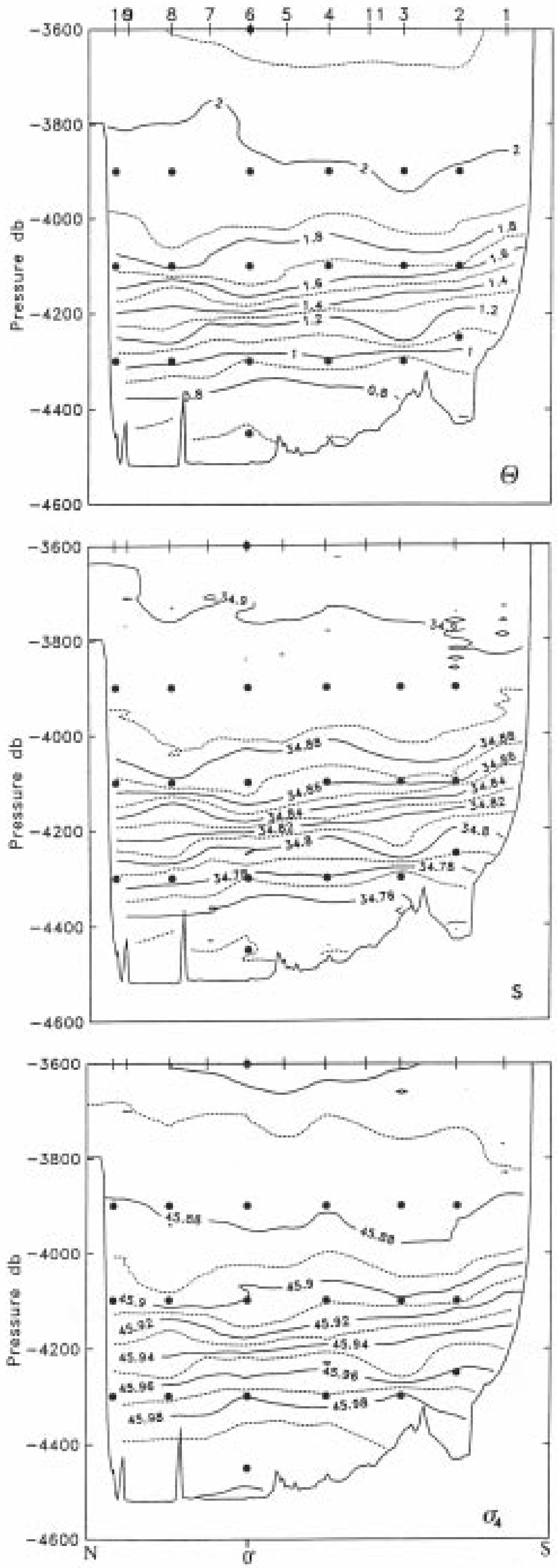

Figure 2. Potential temperature, salinity and σ_4 from the 1994 CTD data across the gap, plotted vs. pressure, at pressures greater than 3600 dbars. CTD station numbers are indicated at the top of the plot. There is an inconsistency between dbars and metres in the figure, so that relative to the vertical axis, bottom depths and instrument locations (shown by dots), plotted in metres, should appear 50–70 dbars deeper than shown. North is to the left; south is to the right.

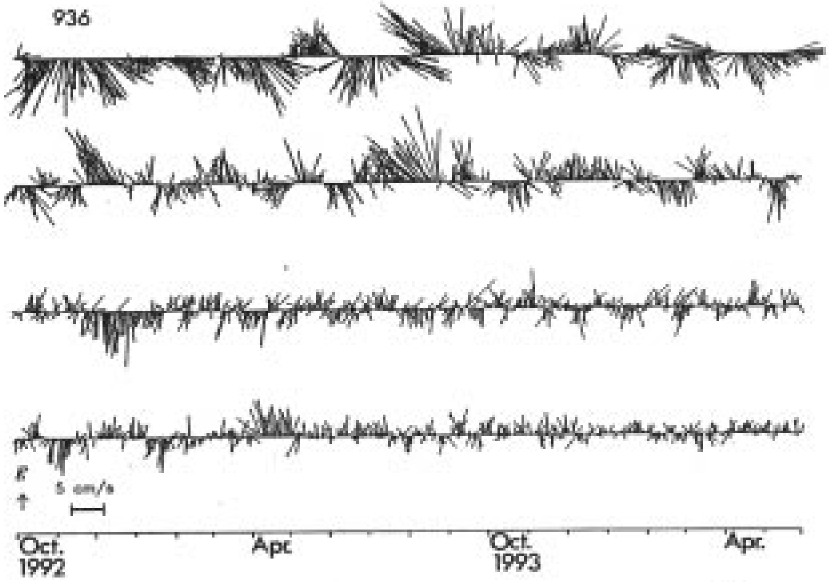

Figure 3. Vector velocity time series for mooring 936, at approximately 1°N. Eastward velocities are up, and the 5 cm s^{-1} scale is shown on the plots. Depths of instruments are (top to bottom) 3297 m, 3896 m, 4096 m, and 4297 m.

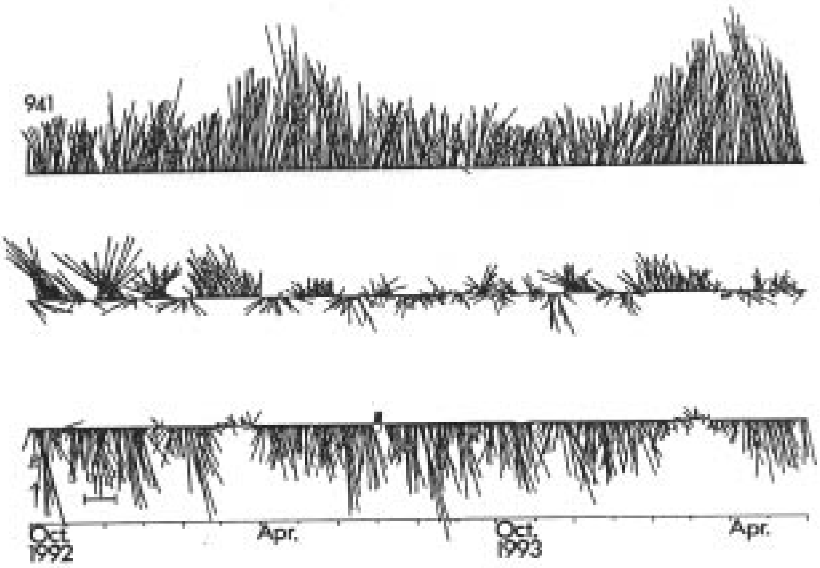

Figure 4. As in Figure 3, but for mooring 941, near 1.5°S. Depths of instruments are 3899 m, 4099 m, and 4300 m.

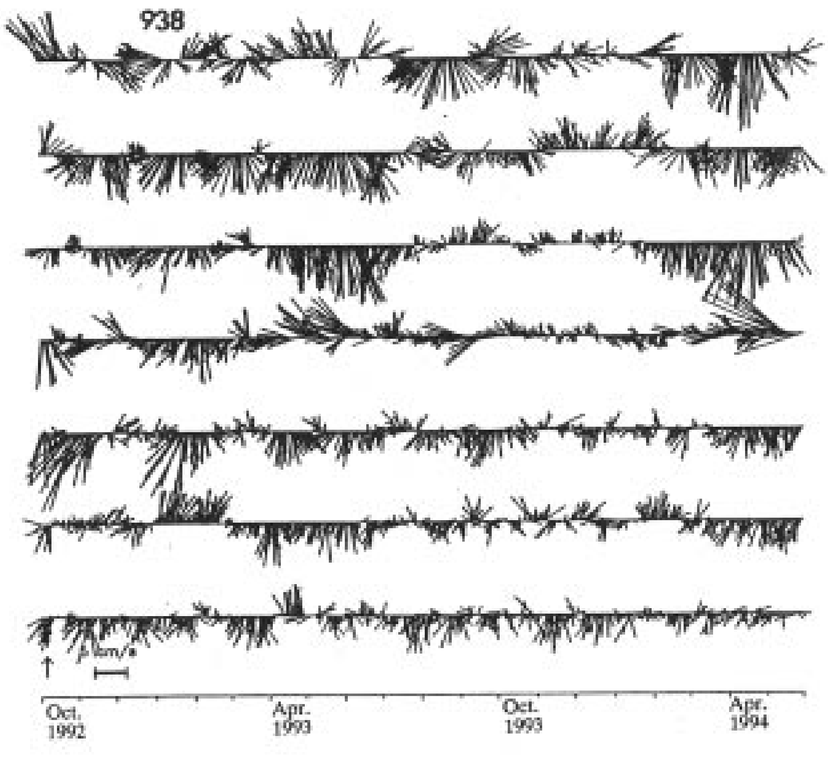

Figure 5. As in Figure 3, but for mooring 938, on the equator. Depths of instruments are 2993 m, 3293 m, 3593 m, 3892 m, 4093 m, 4292 m, and 4485 m.

4300, and 4500 m). What is interesting here is that there appears to be vertical coherence of the flow throughout the water column between 3000 and 4450 m at times. As at mooring 939, mean zonal velocities at 938 are all westward, confirming that eastward flow of NADW is confined south of the equator.

Temperature variance from the moored data at all locations was 2–10 times greater at 4100 m than at other depths, and these records all showed a linear warming trend. The high variance at the 4100 m instruments suggests that they were located near the interface between AABW and NADW, which is characterized by the strong vertical gradient of potential temperature between the two layers. It is not yet clear whether this interface receded downward during the deployment period, or whether the deep and bottom water properties underwent a long time scale change during the time of deployment. Figure 6 shows lowpassed time series for potential temperature at 4100 m (smoothed with a 15-day boxcar filter): the visual coherence between different locations is confirmed quantitatively as well. In fact, cross-correlations between records at 4100 m are significantly higher than either correlations between temperatures at different depths on the same mooring, or cross-correlations between temperature time series at either 3900 or 4300 m.

In summary, preliminary conclusions based on the moored data (presented by J. Whitehead at the South Atlantic Symposium in Bremen, August 1994) include the following:

1. A relatively steady westward (from southern to northern hemisphere) flux of Antarctic Bottom Water exists. The current is strongest in the southern half of the gap, as found by Rhein *et al*.
2. A preliminary estimate of this cross-equatorial flux is about 2.1 Sv.
3. A strong long-lived jet of North Atlantic Deep Water is present above the Antarctic Bottom Water, but is confined south of the equator, in agreement with Rhein *et al.*
4. A warming of about 0.25–0.35°C occurred at 4100 m during the deployment (equivalent to about 0.5°C per 1000 days), accompanied by strong high frequency variability. Neither the warming nor this strong variance occurred at any other depth in the array.

Particular thanks are extended to Richard Limeburner for the CTD work, to Scott Worrilow, Kent Bradshaw, and Larry Costello for the current meter preparation, deployment and recovery, and to Susan Tarbell for current meter data processing.

References

McCartney, M.S., and R. Curry, 1993. Trans-equatorial flow of Antarctic bottom water in the Western Atlantic Ocean. J. Phys. Oceanogr., 23, 1264–1276.

Rhein, M., L. Stramma and U. Send, 1994. The Atlantic Deep Western Boundary Current: Water masses and transports near the equator. J. Geophys. Res. (in press).

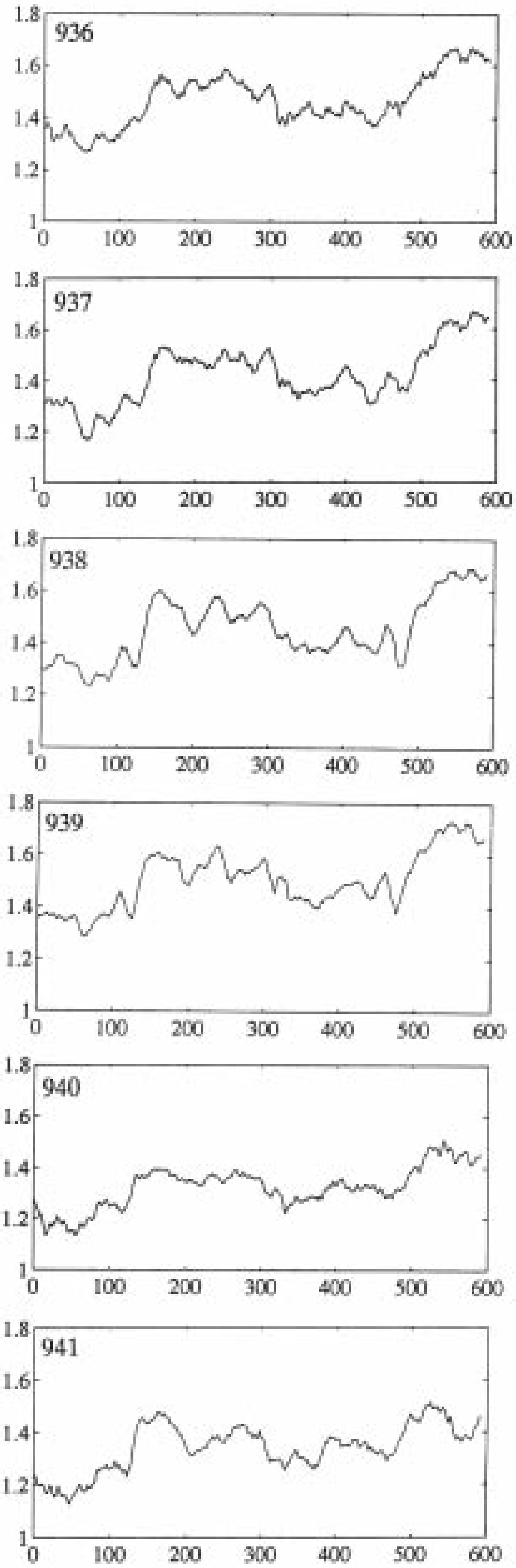

Figure 6. Lowpassed time series of potential temperature at 4100 m from the six mooring locations, for the common time period. The abcissa is sequential days, beginning with 1. The ordinate is °C. The 15-day boxcar filter yields time series that are 590 days in length.

Flow of Antarctic Bottom Water over the Sill in the Romanche Fracture Zone

Herlé Mercier, Laboratoire de Physique des Océans, IFREMER, 29280 Plouzane, France, and
Harry Bryden, James Rennell Centre for Ocean Circulation, Chilworth, Southampton, SO1 7NS, UK.

The distribution of water properties in the Romanche Fracture Zone as presented by Speer *et al.* (1994) is reminiscent of the flow out of a reservoir over a dam. Antarctic Bottom Water (AABW) flowing through a narrow channel piles up behind a deep sill and then cascades over the sill into the eastern Atlantic (Figure 1). Using the arguments for determining flow over a dam, we estimate here the transport of AABW over the sill in the Romanche Fracture Zone.

We model the flow as a three-layer system (Figure 2). There is a level surface of constant pressure, P_0, separating the active deep regions from the shallower flows. We associate this surface with the 2.1°C isotherm that seems to be approximately level in Figure 1. In the deep layers, there is a transition layer of density ρ_1 above the Antarctic Bottom Water reservoir of density ρ_2. For frictionless, steady flow, momentum conservation in the AABW layer can be expressed as conservation of Bernoulli potential along the interface between the transition layer and the AABW reservoir from the upstream reservoir at point 1 to the sill at point 2:

$$\frac{P_0 + \rho_1 g h_1}{\rho_2} + \frac{u_1^2}{2} + gH = \frac{P_0 + \rho_1 g\left(H + h_1 - h_2\right)}{\rho_2} + gh_2 + \frac{u_2^2}{2} \qquad [1]$$

Far upstream of the sill in the deep reservoir at point 1, u_1 is small enough to be neglected so equation 1 can be rearranged to relate the velocity at the sill, u_2, to the height of the reservoir above the sill, H, and to the height of the flow of AABW over the sill, h_2:

$$u_2 = \sqrt{2\frac{\left(\rho_2 - \rho_1\right)}{\rho_2} g\left(H - h_2\right)}\,. \qquad [2]$$

Following procedures for flow over a dam, we argue that the flow over the sill must be a maximum, for the reservoir has filled to a level that allows the source waters for the reservoir to flow over the dam to maintain a steady state. Thus, we maximise the transport of AABW over the sill, $Q_2 = u_2 h_2$, as a function of h_2:

$$\frac{\partial Q_2}{\partial h_2} = 0 = \left(H - h_2\right)^{\frac{1}{2}} - \frac{h_2}{2}\left(H - h_2\right)^{-\frac{1}{2}} \qquad [3]$$

to determine $h_2 = \frac{2H}{3}$. This, of course, implies that the Froude number at the sill is critical $\dfrac{u_2^2}{g\left(\dfrac{\rho_2 - \rho_1}{\rho_2}\right)h_2} = 1$, so the flow is said to be hydraulically controlled. For this maximum exchange, the transport of the bottom layer over the sill is a function only of the height of the reservoir above the sill and the density difference between the reservoir and the transition waters:

$$Q_2 = \frac{2}{3} H \sqrt{\frac{2}{3} g \frac{\left(\rho_2 - \rho_1\right)}{\rho_2} H}\,. \qquad [4]$$

To make a transport estimate for the AABW over the sill in the Romanche Fracture Zone, we examine the distribution of potential temperature in Figure 1 to estimate that: (a) the 2.1°C isotherm can be taken to represent the level surface with constant pressure P_0; (b) the 1.9°C isotherm can be taken to define the upper limit of the AABW flow cascading over the sill; and (c) 1.2°C water appears to be the coldest AABW water making it over the sill. Hence, we take the density difference to be that between 2°C water, where 2°C is the average temperature of the transition layer, and 1.55°C water, where 1.55°C is the average temperature of AABW flowing over the sill, referenced to 4000 dbar. The resulting density difference is 4.7 x 10^{-5} g cm^{-3}. From stations 4, 9, 10, 15, and 18 (Mercier *et al.*, 1992), we estimate the average depth of the 1.9°C isotherm in the upstream reservoir to be 3870 m, or 480 m above the sill depth of 4350 m reported by Speer *et al.* (1994). Finally, from the detailed chart for the bathymetry of the Romanche Fracture Zone (Monti and Mercier, 1991), we estimate the width of the channel near the sill to be 20 km. The resulting transport of Antarctic Bottom Water over the sill in the Romanche Fracture Zone into the eastern Atlantic is then 2.4 Sv. Such transport is about half of the 4.3 Sv of AABW transport found by McCartney and Curry (1993) to be flowing westward along the equator at 37°W, out of the South Atlantic into the North Atlantic. Most of the AABW transport into the North Atlantic is traditionally assigned to the western basin, as the AABW signature is stronger in the western basin. It is possible, however, that the transports into the eastern and western basins are comparable but that the mixing as the AABW cascades over the sill in the Romanche Fracture Zone masks the signature of AABW in the eastern basin.

Deep sills controlling the exchange between basins offer convenient locations for measuring the deep circulation and monitoring its changes. With maximum exchange arguments, it is possible to measure and monitor

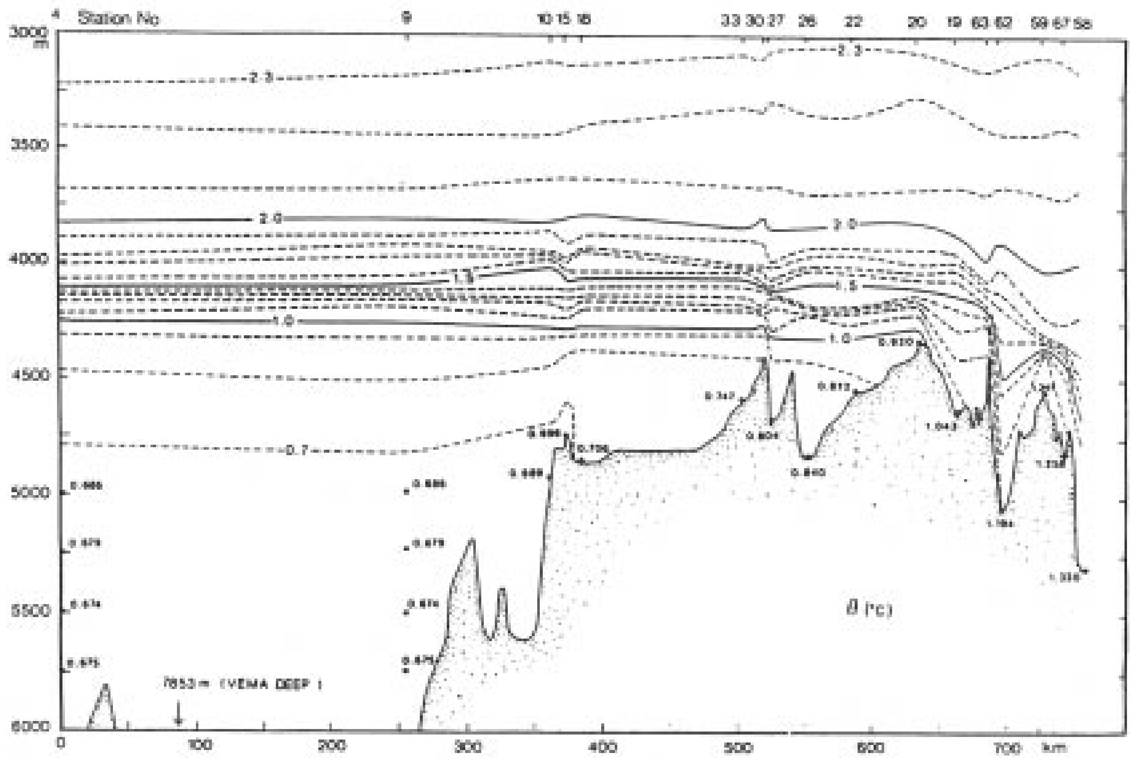

Figure 1. Potential temperature (°C) below 3000 m depth along the axis of the Romanche Fracture Zone. Bottom profile represents the deepest point of the fracture; the walls on either side are typically 3000–3500 m deep, so the section is mostly within the fracture zone. This is Figure 2 of Speer et al. (1994). For location of station 4-58, see Newsletter No. 16.

the flow over the sill by simply measuring the height of the upstream reservoir above the sill. It is, of course, possible that the flow is not maximal at all times, for example the reservoir may fill seasonally and the flow remains hydraulically critical only until the annual intake has spilled over the sill. Continuous measurements of the upstream height of the reservoir, however, could offer a simple means to monitor changes in the reservoir and the flow over the deep sills.

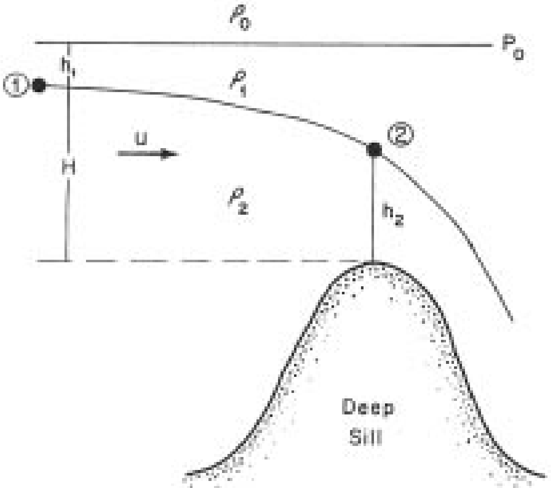

Figure 2. Schematic for three-layer model for the flow over the deep sill in the Romanche Fracture Zone. A level surface of constant pressure P_0 separates the upper waters of density ρ_0 from the deep water of density ρ_1. The height of the bottom water reservoir of density ρ_2 above the sill is H. The interface between the bottom water and the deep water above slopes down toward the sill where it has a height of h_2 as the bottom water cascades over the sill. The velocity of the bottom water flow is u.

References

McCartney, M.S., and R.A. Curry, 1993. Transequatorial Flow of Antarctic Bottom Water in the Western Atlantic Ocean: Abyssal Geostrophy at the Equator. J. Phys. Oceanogr., 23 (6), 1264–1276.

Mercier, H., A. Billant, P. Branellec, P. Morin, M.-J. Messias, L. Mémery, C. Thomas and J. Honnorez, 1992. Campagne Romanche 1, l'Atalante (10 Août–8 Septembre 1991), Données $CTDO_2$, Chimie et Bathymétrie. Laboratoire de Physique des Océans, Unité Mixte de Recherche No. 127, Rapport Interne LPO 92-02.

Monti, S., and H. Mercier, 1991. Romanche Fracture Zone. Chart: Préparation à l'Impression par BEICIP, Rueil-Malmaison, pour IFREMER, Direction de l'Environnement et des Recherches Océaniques, Département des Géosciences Marines.

Speer, K., H. Mercier, M.-J. Messias and L. Mémery, 1994. The Romanche Fracture Zone: Blocking and Mixing of Arctic and Antarctic Waters at the Equator. International WOCE Newsletter, 16, 8–11.

AIM: The Atlantic Isopycnic Model

Adrian L. New, James Rennell Centre for Ocean Circulation, Gamma House, Chilworth Research Centre, Chilworth, Southampton, SO1 7NS, UK.

The Atlantic Ocean is important because of its influence on the world's climate. Warm near-surface waters flow northwards and release their heat to the atmosphere in the wintertime at high northern latitudes. This results in sinking and the production of deep cold return flows to the south. The whole process has been dubbed the "Atlantic Conveyor Belt" (Broecker, 1991) and is responsible for a large heat exchange to the atmosphere. It is therefore important to understand the processes which contribute to the heat transport and circulation in the Atlantic.

Isopycnic-coordinate models, consisting of a set of layers of constant density but varying thickness, are now emerging as a useful tool for the investigation of these ocean processes. These models are in contrast to the more usual gridpoint models which have a set of levels at fixed positions in the vertical at which the model variables are known, and which have been in use for many years. Isopycnic models may possess certain advantages over the gridpoint models, but so far most ocean modelling studies and climate prediction models have been based around the gridpoint models.

It is therefore important to intercompare these two model types to assess their relative merits. With this in mind, the James Rennell Centre for Ocean Circulation has implemented the Miami Isopycnic Coordinate Ocean Model (MICOM) to describe the Atlantic Ocean from about 15°S to 80°N. A 30-year integration has been carried out at a resolution of about 1° horizontally (latitude-longitude), and this run has been analysed in detail. As a collaborative exercise, the Hadley Centre for Climate Prediction and Research (part of the UK Meteorological Office) has carried out a parallel integration with a gridpoint model, and significant differences are now emerging. In particular, the overall amount of heat carried northwards differs by more than 30% between the two models, and there are significant differences in the outflows of deep water masses across the Greenland-Iceland-Faeroes rise, and in the path of the North Atlantic Current. These discrepancies are likely to cause large differences in climate models which may be integrated for long periods, but it is still too early to say precisely what causes the differences, although further study is in progress.

Further analysis of output from the 1° resolution isopycnic model has revealed significant insights into the interdecadal variability of the ventilated portion of the North Atlantic subtropical gyre (*i.e.* the top 800 m or so of the water column between 10–40°N). In particular, we have been able to explain changes reported to have occurred in recent decades in the real world (such as cooling on constant depth levels but warming on constant density surfaces) as having been caused by the drawdown (subduction) of cooler water masses from the mixed layer. In addition, the analysis of various tracers confirms that water masses in the upper ocean are indeed formed principally by the subduction of water masses from the mixed layer rather than by vertical mixing and diffusion, and heat budget studies in the Labrador Sea area have revealed the relative importance of oceanic advection as compared with air-sea transfers. Finally, further sensitivity studies are showing that historical changes in the composition of the water masses in the Sargasso Sea are likely to have resulted from cold-air outbreaks from the North American continent in severe winters.

AIM is now also being run at a higher horizontal resolution, about $^1/_3$°, which is sufficient to allow eddies to form. Eddies are too small to be adequately described by typical climate models, which for reasons of computer size and speed, usually have a grid spacing of 1° or 2° horizontally (1° latitude equals 111 km). Nevertheless, it may be that these eddies contribute significantly to the basin-averaged northward heat transport and also to the interactions and transfers between the ocean surface and its interior. It is therefore necessary to perform model integrations containing eddies so that these effects can be studied and, if found to be important, so that parameterisations can be developed for inclusion in the climate models. Several tests with the Miami code have now been undertaken and work has concentrated on varying the available diffusion parameters to obtain a realistic eddy field. The model now produces a reasonable field of eddies. For example, as in the real world, cyclonic (anti-clockwise) cold-core eddies have been observed south of the Gulf Stream, with corresponding anticyclonic warm-core features to the north. One example is shown in Figure 1, which reveals the sea-surface temperature and current structure in one of the eddy-resolving runs just south of Nova Scotia (the cold-core eddy occurs at 58°W, 41°N, the warm eddy at 57°W, 43°N). The net effect of these eddies must be to increase the northward heat transport, at least locally across the Gulf Stream, since cold water from north of the current is being drawn southwards, to form the cold-core feature, and conversely for the warm feature. Collaboration is now beginning with similar modelling groups in Germany and France to intercompare three different model types at eddy resolution, in order to assess their relative merits. The eddy-resolving AIM model will be used to help interpret observations collected under the WOCE programme.

The 1° resolution version of the isopycnic model has been run on 8-processor CRAY YMP supercomputers at both the Hadley Centre and at the Rutherford Appleton Laboratory (RAL), whilst the eddy-resolving model has

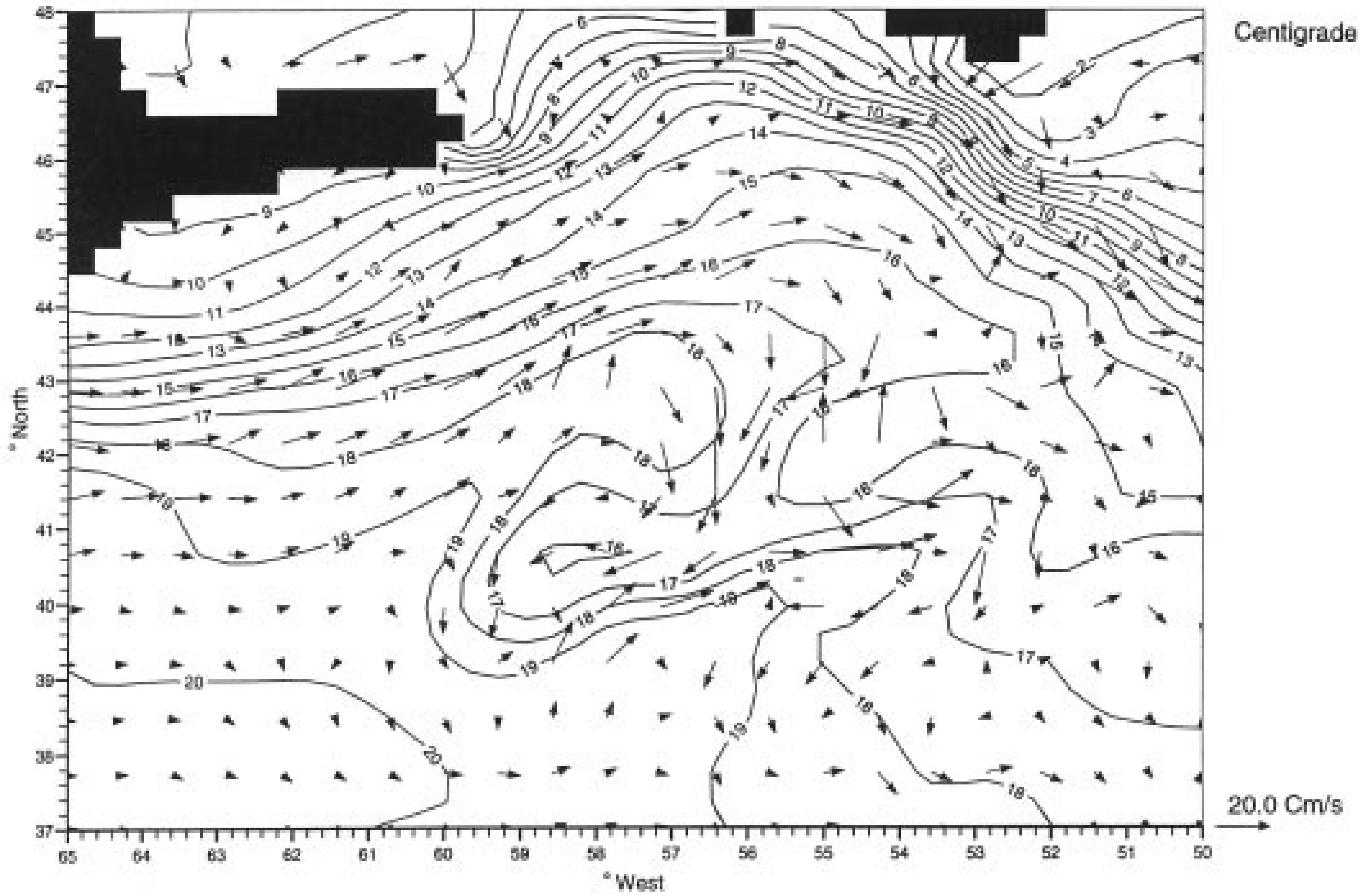

Figure 1. Sea surface temperature and currents south of Nova Scotia from the $^{1}/_{3}$° model.

been implemented solely at RAL. The former model typically runs on a single processor with a grid size of 126 x 104 points and 20 layers in the vertical, in which configuration it takes about 9 MWords of core memory and 6 cpu hours for a single year of integration. The eddy-resolving model, however, has a grid size of 376 x 310 points (again with 20 layers in the vertical) and takes about 85 MWords of core memory, nearly filling the machine. This means that this model is usually autotasked across all 8 processors, and speed-ups (compared with running on a single processor) of 5.5–6.0 times are typically obtained, giving a total speed of about 500–600 MFlops (million floating point operations per second). The eddy-resolving model takes about 180 (single processor) cpu hours to complete a year of simulation. Full data dumps from the 1° model are usually obtained every month of simulation time, and require about 3 Mbytes of storage, whereas dumps from the eddy-resolving model are obtained every 12 days and require about 25 Mbytes each. To date, the 1° model has been run for a total of about 100 years, and the eddy resolving model for about 12 years.

Further details of the model and the some of the results outlined above are contained in New *et al.* (1995) and New and Bleck (1995), copies of which can be obtained from the author.

References

Brocker, W.S., 1991. The Great Ocean Conveyer. Oceanography, 4, 79–89.

New, A.L., R. Bleck, Y. Jia, R. Marsh, M. Huddleston and S. Barnard, 1995. An isopycnic model study of the North Atlantic. Part 1: Model experiment. Submitted to Journal of Physical Oceanography.

New, A.L., and R. Bleck, 1995. An isopycnic model study of the North Atlantic. Part 2: Interdecadal variability of the subtropical gyre. Submitted to Journal of Physical Oceanography.

New Depth Equation for Commonly Used Expendable Bathythermographs: Sippican and TSK T-4, T-6 and T-7 probes

P. Rual, ORSTOM, Surtropac Group, Noumea, New Caledonia; K. Hanawa, Tohoku University, Department of Geophysics, Sendai 980, Japan; R. Bailey, CSIRO, Division of Oceanography, Hobart, Tasmania 7001, Australia; A. Sy, Bundesamt für Seeschiffahrt und Hydrographie, D-20359 Hamburg, Germany; and M. Szabados, NOAA/NOS-OOES, Silver Spring, MD 20910-3233, USA.

Introduction

Expendable oceanographic probes, in particular expendable bathythermographs (XBT) launched from ships-of-opportunity, have been a significant component of many large scale oceanographic research programmes, such as the Tropical Ocean Global Atmosphere (TOGA) Programme and the World Ocean Circulation Experiment (WOCE). These probes will no doubt also be heavily relied upon in future operational oceanographic programmes such as the proposed Global Ocean Observing System (GOOS), and there will be a growing need to utilise these instruments to the limits of their accuracies.

The depth of an XBT probe is not directly measured, but is inferred from an assumed fall rate. The existence of a depth error in the XBT data has been pointed out by several authors (*e.g.*, Flierl and Robinson, 1977; Seaver and Kuleshov, 1982). Several investigators have since estimated revised depth-time (fall rate) equations for the XBT using a number of different techniques. In addition, Green (1984) provides a detailed description of the hydrodynamics of XBTs. These revisions were generally calculated from experiments in a single area of the ocean. Therefore the Integrated Global Ocean Services System (IGOSS) Task Team on Quality Control for Automated Systems (TT/QCAS) initiated an international effort to conduct further XBT/CTD comparison tests, in as many oceanic regions as possible and under controlled experimental conditions, in order to develop new equations for universal use. The probes evaluated were the commonly used Sippican and Tsurumi-Seiki (TSK) T-7 or Deep Blues (760 m), T-6 and T-4 (460 m) types of XBT, all of which use the same manufacturers' depth-time equation. Full results of this study can be found in UNESCO (1994) or in Hanawa et al. (1994). The present paper focuses on the determination of a new unique reference depth-time equation. The scatter of the fall rates is compared to the manufacturers' specifications. A depth correction formula is derived for correcting archived data.

XBT/CTD comparison experiment

Between 1985 and 1992, 28 XBT/CTD comparison experiments were carried out by five institutions and by one manufacturer in different regions (see Figure 1). A total of 372 profiles were collected: 161 T-7 XBT and 211 T-4/T-6. All XBT data are evaluated relative to a field standard, the conductivity-temperature-depth (CTD) profiler. The CTD profilers were calibrated before and after each voyage of the research vessels involved, and the calibration results were applied to the CTD data before analysis. Therefore CTD data errors are at least an order of magnitude smaller than XBT data errors and, for this study, will be considered as negligible. A number of different digital XBT recorders were used to collect the XBT data. Each XBT recorder underwent a calibration check before and after each voyage. A "side by side", XBT/CTD comparison was the main improvement in the field procedures used in this study compared to most of the previous investigators' studies. Generally, XBTs were dropped within 10–15 minutes of the start of descent of the CTD, so as to coincide with the CTD within the thermocline. This was an attempt to eliminate as much as possible depth-differences due to temperature-field variations in time or space (*e.g.* internal waves).

New Reference Depth-time Equation

Provided that the onboard XBT equipment is working correctly, it is considered that there are two main error-sources in XBT data: (i) Depth-errors due to an inaccurate depth-time equation for the fall rate of the probes; (ii) Temperature errors due to the scatter of thermistor responses and inaccuracies in the conversion of thermistor resistance to temperature. In this study we will only examine the depth-errors associated with inaccuracies in the fall rate equation.

For T-4, T-6 and T-7 XBTs, the depth-time equation provided by the XBT manufacturers is:

$$zm = 6.472\ t - 0.00216\ t^2 \qquad [1]$$

where zm is the depth and t is the elapsed time in seconds starting when the probe hits the surface. The linear coefficient is a function of the hydrodynamic characteristics of the probe in the water, while the quadratic coefficient is a function of the change in mass of the probe (unreeling of the wire) and of the change with depth of the water characteristics (density and viscosity gradients, see Green, 1984).

Hanawa and Yoritaka (1987) and Hanawa and Yoshikawa (1991) first developed a temperature-error-free method for determining errors in the depth-time equation. The essence of the method is that comparison with the field standard should be made not for the absolute temperature profiles but for the temperature gradient profiles. This is because temperature errors are directly related to depth errors, and bias-like temperature errors can be eliminated by using the temperature gradient information. The detection method adopted for the depth-error in the present analysis is an extension of this method. It was first independently developed by Hanawa and Yasuda (1992) and Rual (1991), and was further simplified and modified for better accuracy (for full details see UNESCO, 1994, or Hanawa *et al.*, 1994).

The new reference equation for the mixed T-4, T-6 and T-7 data set becomes (at a confidence level of 95%):

$$Z = (6.691 \pm 0.021)\ t - (2.25 \pm 0.30) 10^{-3}\ t^2 \qquad [2]$$

The T-7 as well as the T-4/T-6 mean coefficients (not shown) are within one standard-error-of-the-mean from the reference coefficients. The maximum absolute depth-error between the above reference equation and the T-7's equation is -0.8m or -0.1% at 800 m (actual depth generally reached by the probes) and, for the T-4/T-6's equation, it is -0.2 m or -0.06% at 264 m. These results confirm that a single reference T-4/T-6/T-7 depth-time equation can replace, with very reasonable accuracy, the original manufacturers' equation.

Remarks on the present method. The present method can be applied to any temperature profile irrespective of the existence of extrema, and the data points are evenly distributed over the whole depth range. It is more automatic than previous methods, and demands only visual inspection of the depth-difference profiles to check the depth-time pairs. However, the new method does occasionally fail to detect depth-differences when the vertical temperature gradient is constant in a section of the profile larger than the search window (see UNESCO, 1994, for details), or when the XBT temperature profile has features not matched by the CTD profile. These non-coherent depth-differences can be discarded by visual inspection of the depth-difference profiles.

Observed Variability and the Manufacturers' Specifications

Figure 2a shows the distributions of the 5895 valid depth-differences (using the manufacturers' equation 1), as a function of their CTD depth, for the combined T-4/T-6/T-7 data set. The elapsed times corresponding to the depth-differences are identical for each profile, therefore all the

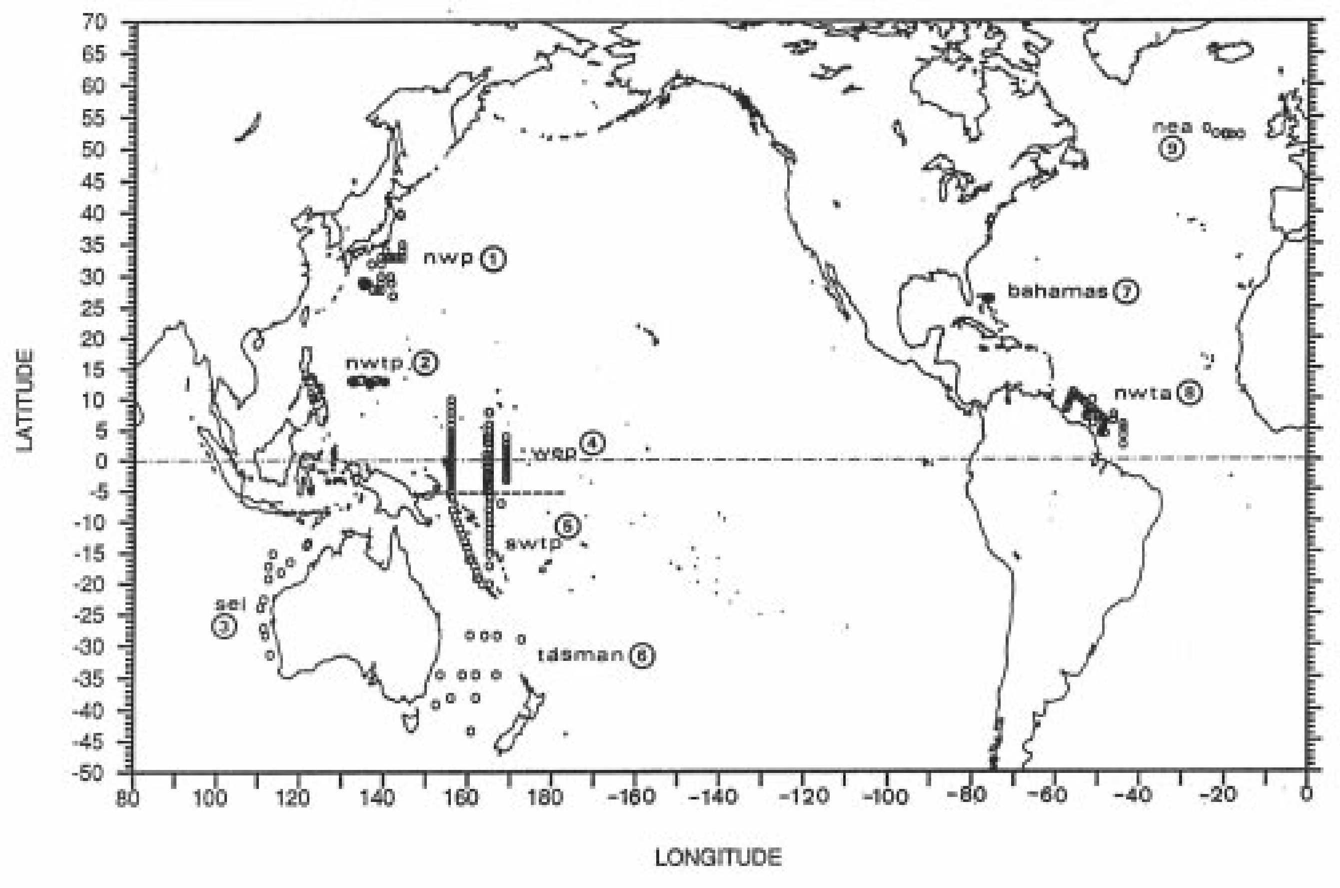

Figure 1. Locations where the CTD-XBT comparison experiments were conducted. The dashed line at 5°S in the western Pacific shows the limit between the wep and swtp data sets.

depth-differences at a given elapsed time can be grouped together to determine the depth-difference statistics for that given time (here every 25 "XBT-metre"). At each level the distribution of the depth-differences are quasi-normal and only a slight asymmetry in the scatter can be noted towards the high fall rate side of the distribution (high negative individual depth-errors). The data are generally outside the manufacturers' specifications (±5 m or ±2% whichever is the greatest), except close to the surface where the mean depth-error is within ±5 m down to a depth of 150 m. The mean depth-errors range from -2.5 m at 100 metres to -24.5 m at 775 m. Only the very slow fall rates, outside minus one standard deviation (about 15% of the data), are within the specifications almost down to the maximum depth.

When the new reference equation 2 is used instead of the original manufacturers' equation 1 (Fig. 2b), the mean depth-error is greatly reduced and is now within ±1 m of the CTD depth. However, 17.5% of the individual depth-errors are still outside the manufacturers' specifications (1028 depth-errors out of a total of 5895). Only the 1-standard deviation confidence interval is entirely within those specifications, and one must reach the maximum depth for the 2-standard deviation curves to be close to the specifications. A linear approximation of the 2 and 3 standard deviation curves (dotted lines in Fig. 2b) gives respectively:

$$\pm (6 \text{ m} + 1.5\% \text{ of the depth}) \qquad [3]$$

$$\pm (9 \text{ m} + 2.0\% \text{ of the depth}) \qquad [4]$$

If the meaning of a specification is that the depths of all the probes should be within them, then the specifications provided by the manufacturers should be at least of the order of equation 4. It must be noted that the new specifications are not ±n metres or ± p%, but ±(n metres plus p%). The shallow depth specifications, therefore, are much larger than they used to be: above ±10 m at 100 m and around ±15 m at 250 m, instead of ±5 m. Hallock and Teague (1992) found the same kind of probe-to-probe scatter after correction of the original data with their new equation: about ±8 to 10 m in the depth range 10 m to 100 m, and ±15 to 20 m in the range 450 m–650 m.

It should be noted that the linearity of the standard deviation curves with depth is a good index of the reliability of the method used to calculate the depth-errors. All over the depth range, the relative scatter of the probes remains constant, about 1.5% of the depth at a 95% confidence level. Therefore, if the general behaviour of the probes with depth remains similar from probe to probe, the reliability of the method remains constant whatever the depth, even when the vertical temperature gradients change only slightly.

Depth Correction Formula for Archived XBT Data

The mean depth-error curve in Figure 2a is almost linear, thus a linear correction approximation only will be presented here to correct XBT depths (zm) calculated using the original manufacturers' equation 1. In order to minimise the absolute depth-error while keeping the relative depth-error within reasonable bounds in the first hundreds meters (see UNESCO, 1994), the best linear approximation (Zl) adopted for correcting the depth is:

$$Zl = 1.0336\, z_m \qquad [5]$$

The maximum errors induced by using this linear coefficient are less than -0.1 m at 800 m for the T-7 probes, and less than 0.05 m at 300 m for the T-4/T-6 probes. The relative depth-error is less than ±0.03% for all depths. Thus the linear correction approximation is very accurate for these probes, but this may not be always true for other probe types and other manufacturers.

Discussion and Recommendations

A unique new reference T-4/T-6/T-7 fall rate equation was conclusively determined by a temperature-error-free method applied to a number of XBT/CTD comparison data sets which were collected in three oceans and under controlled conditions. Unfortunately, there were no opportunities to collect comparison data sets in polar regions or other extreme oceanic conditions, but no significant regional, onboard equipment, or probe manufacturer influence on the fall rate was detected, except perhaps a regional influence in the north-eastern Atlantic, and a manufacturing difference in the TSK T-6 probes (see UNESCO, 1994, and Hanawa *et al.*, 1994, for detailed discussion). Any influences, if they do exist, are masked by the large individual, or batch-to-batch variability of the probes' characteristics; especially of the T-4/T-6 probes. The reason for this variability is undetermined. The maximum depth-differences between our reference equation 2 and the results previously published by other investigators fall well within ±2%. Hence our results do not in general contradict these authors (see also Hanawa *et al.*, 1994, or UNESCO, 1994, for detailed discussion), but add significantly to their findings, whilst also being applicable to a greater part of the world's oceans.

It should be noted that the other types of Sippican/TSK probes, as well as probes produced by other manufacturers such as Sparton of Canada, will also need careful independent evaluation. It is important that each probe type (including different manufacturers) be evaluated to avoid inconsistencies occurring in the depth accuracies of XBT data stored in the national and international data centres. Indeed, until an international mechanism is established to implement general use of a new equation for the T-7, T-6 and T-4 XBTs, and until the equation used for depth determination, the probe type, and the probe manufacturer can be distinguished in the data archives (adoption of a new bathy-code), it is strongly advised that for the present time all XBT data sent to the national or international data centres include depths calculated from the original manufacturer's equation only. The existence of mixed data in the databases must be absolutely avoided.

Acknowledgements

The support of the International Oceanographic Commission and of the World Meteorological Organisation is acknowledged, as well as the input of John Withrow and the help of Melanie Jenard. Sippican Inc. provided technical and background information. We are also indebted to all those involved in the field acquisition and in the processing of the data.

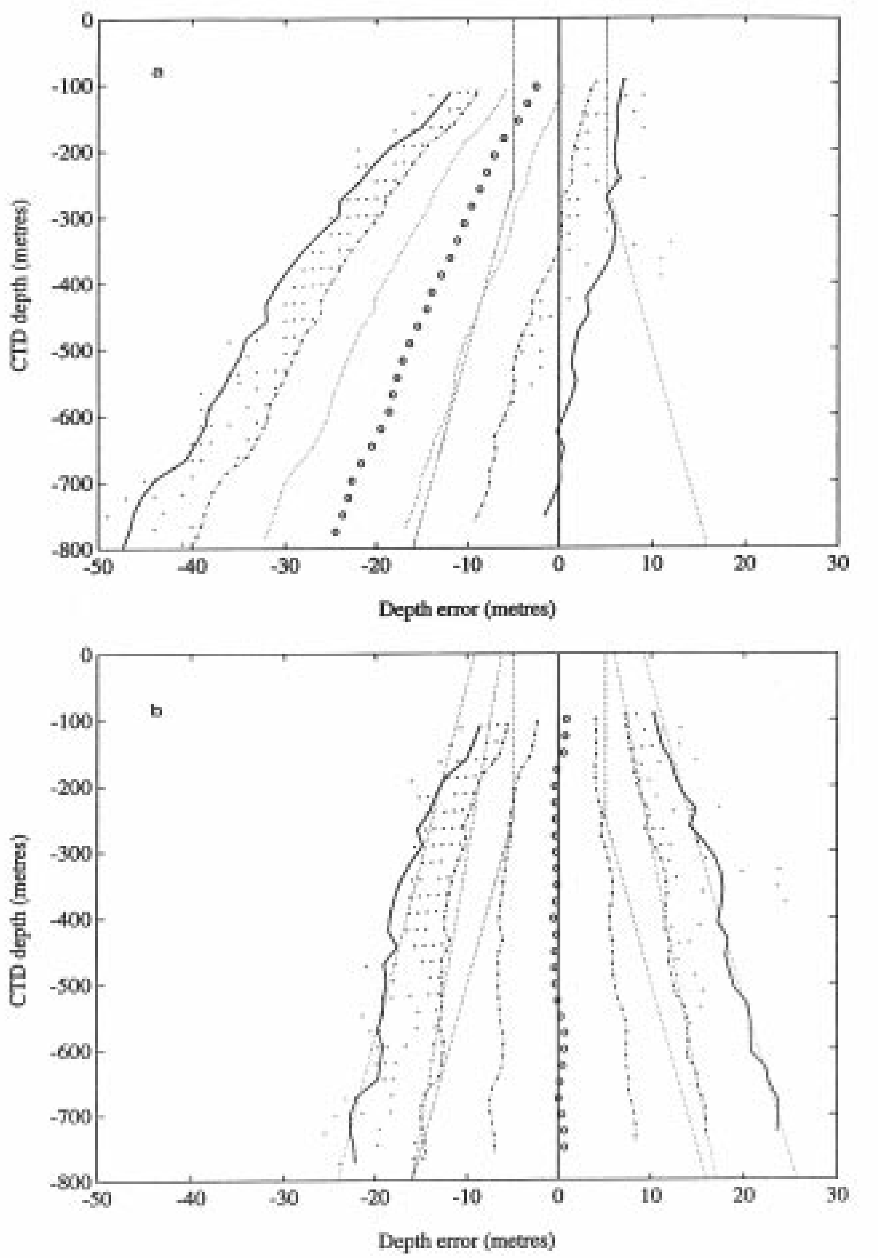

Figure 2. Combined T-4/T-6/T-7 data set: depth-errors and their statistics as a function of depth. (a) Using the manufacturers' depth-time equation 1. Mean depth-error (open circles) and the 1, 2, 3 standard deviations curves (respectively dotted, dash-dotted and full curves). The individual depth-errors above 2 standard deviations are also added (dots). The manufacturers' specifications (±5 m or ±2% of the depth, whichever is the greater) are indicated as dotted lines. (b) Same figure, but using the new T-4/T-6/T-7 reference equation 2. Linear approximations of the 2 and 3 standard deviation curves are also indicated as dotted lines.

References

Flierl, G., and A.R. Robinson, 1977. XBT measurements of the thermal gradient in the MODE eddy. J. Phys. Oceanogr., 7, 300–302.

Green, A.W., 1984. Bulk dynamics of the expendable bathythermograph (XBT). Deep-Sea Res., 31, 415–426.

Hallock, Z.R., and W.J. Teague, 1992. The fall rate of the T-7 XBT. J. Atmos. Oceanic Technol., 9, 470–483.

Hanawa, K., and H. Yoritaka, 1987. Detection of systematic errors in XBT data and their correction. J. Oceanogr. Soc. Japan, 32, 68–76.

Hanawa, K., and Y. Yoshikawa, 1991. Re-examination of depth error in XBT data. J. Atmos. Oceanic Technol., 8, 422–429.

Hanawa, K., and T. Yasuda, 1992. New detection method for XBT depth error and relationship between the depth error and coefficients in the depth-time equation. J. Oceanogr., 48, 221–230.

Hanawa, K., P. Rual, R. Bailey, A. Sy, and M. Szabados, 1994. A new depth-time equation for Sippican or TSK T-7, T-6 and T-4 expandable bathythermographs (XBT). (Accepted by Deep-Sea Res.).

Rual, P., 1991. XBT depth correction. Addendum to the Summary Report of the *Ad Hoc* Meeting of the IGOSS Task Team on Quality Control for Automated Systems, Marion, Massachusetts, U.S.A., June 1991, IOC/INF-888 Add, 131–144.

Seaver, G.A., and A. Kuleshov, 1982. Experimental and analytical error of the expendable bathythermograph. J. Phys. Oceanogr., 12, 592–600.

UNESCO, 1994. Calculation of new depth equations for expendable bathythermographs using a temperature-error-free method (application to Sippican/TSK T-7, T-6 and T-4 XBTs). UNESCO Technical Papers in Marine Sciences, 67, in press.

Satellite Scatterometers

Trevor Guymer, James Rennell Centre for Ocean Circulation, Gamma House, Chilworth Research Centre, Chilworth, Southampton, S01 7NS, UK

The contribution of scatterometers to WOCE

Surface winds are needed in the calculation of the air-sea fluxes of momentum, sensible heat, water vapour and gases using the bulk aerodynamic approach. Several spaceborne sensors are capable of providing winds over the ocean giving much better spatial coverage than can be obtained from *in situ* measurements. However, only one of these, the scatterometer, has demonstrated a capability of retrieving both wind speed and direction.

The satellite scatterometers flown to date are on NASA's Seasat, which operated for 3 months in 1978, and ESA's ERS-1, launched in July 1991 and still functioning well in November 1994. An identical instrument will be carried on ERS-2, scheduled for late January 1995. (At the time of writing it is planned that, after a few months during which the two satellites will be intercalibrated, ERS-1 will be placed in a standby mode ready to be activated should ERS-2 fail). In 1996, a NASA scatterometer will be carried onboard Japan's Advanced Earth Observation Satellite, ADEOS. So, there are good prospects for continuity of scatterometer data from mid 1991 until the end of the WOCE period.

Characteristics of the ERS-1 scatterometer

The Seasat experience indicated that wind speed and direction could be estimated to 2m/s and 20° respectively. However, directional ambiguities were a major problem in the use of the data which, for large-scale, long-period applications, could only be overcome by the use of background wind fields obtained from the analysis phase of meteorological forecast models. Using such a dataset Chelton *et al.* (1990) generated global wind stress fields and computed the associated Sverdrup circulation. On ERS-1 a third antenna was added (Figure 1) which allows most of these ambiguities to be removed without reference to external information. A significant proportion are still in error by 180° and for these model data must still be used.

Although ERS-1 uses a different radar frequency from Seasat (5 GHz instead of 14 GHz) the wind velocity appears to be of similar accuracy (Figure 2). However, because there were

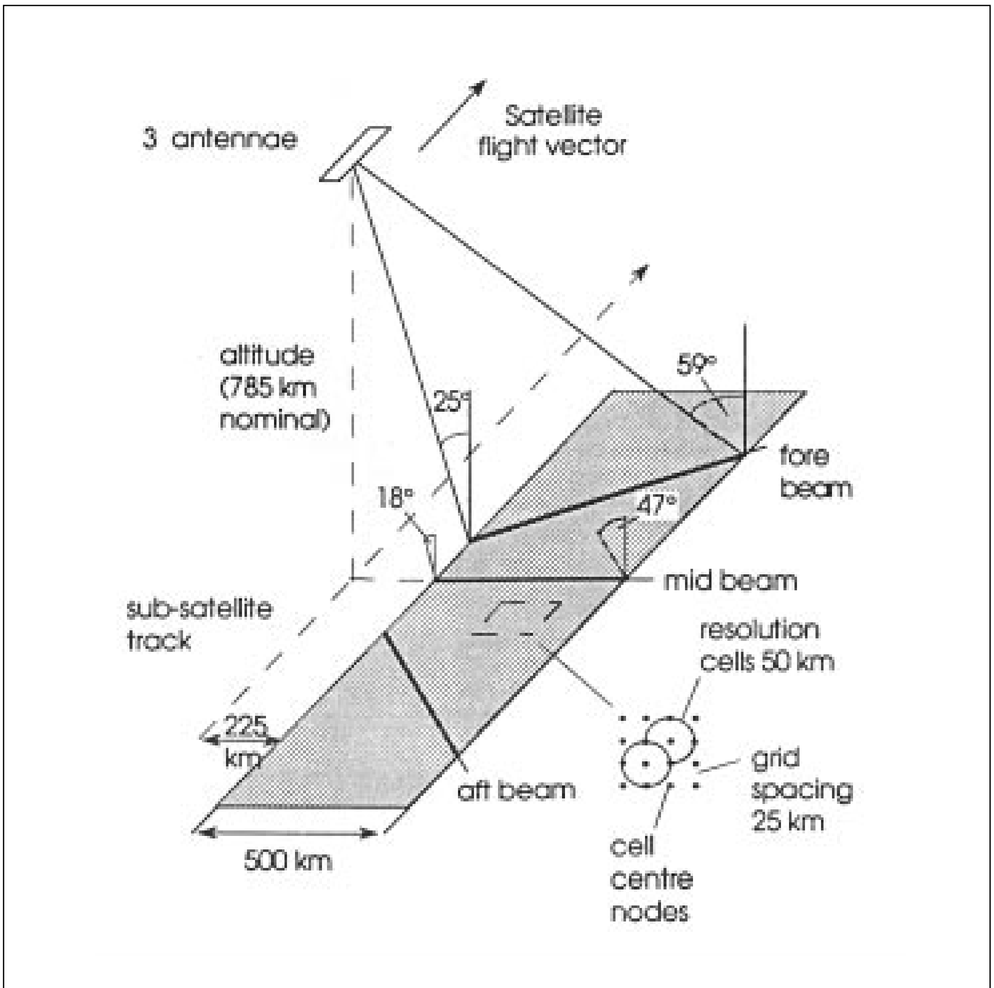

Figure 1. Geometry of the ERS-1 scatterometer

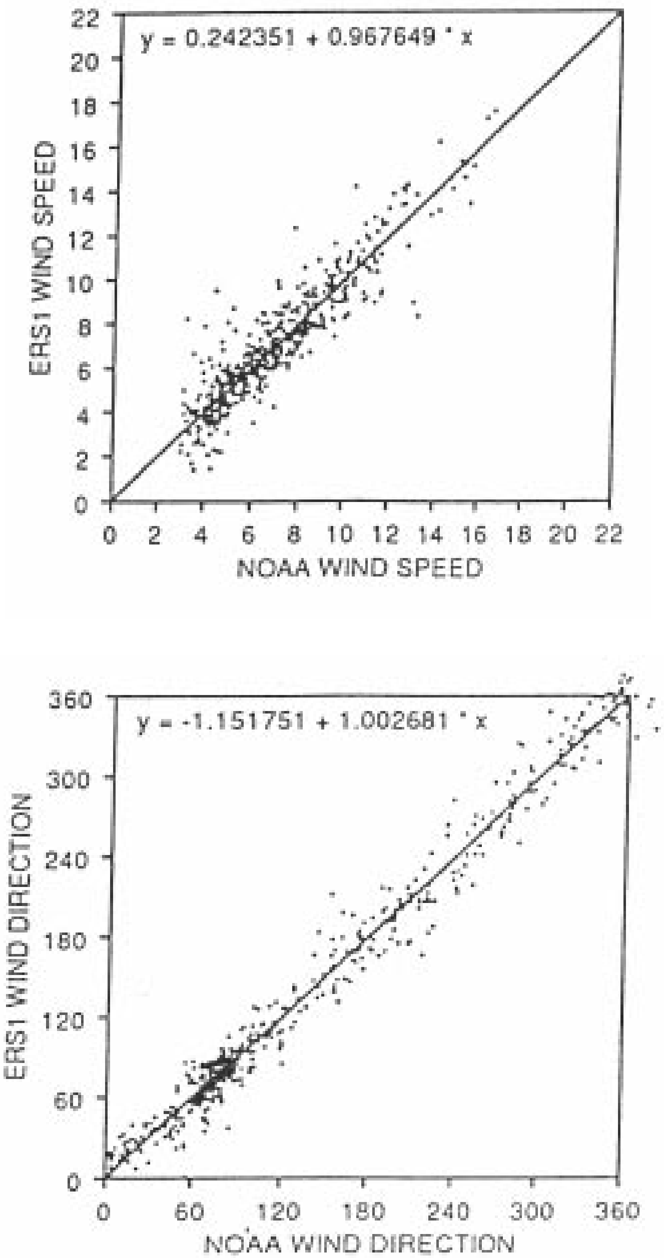

Figure 2. Comparison of ERS-1 scatterometer winds with NOAA buoys. Upper: wind speed, lower: wind direction (from Katsaros et al., pp. 61–66 in ESA, 1993)

relatively little data at this frequency before the launch of ERS-1 it has taken a long time to develop an acceptable algorithm. The ERS-1 scatterometer is part of the Active Microwave Instrument (AMI) which also includes the Synthetic Aperture Radar (SAR). This enables the two sensors to operate at the same frequency so that they respond to the same scales of surface roughness. One adverse consequence of this shared arrangement is that they cannot be operated simultaneously; when the AMI is operating in full SAR-imaging mode there are no wind fields. Potential users need to be aware of this if their area of interest is one in which intensive SAR operations are also likely.

Recent results from ERS-1

Preliminary results obtained with the scatterometer have appeared in the proceedings of two ERS-1 symposia organized by the European Space Agency (ESA, 1993; 1994). At the first, the emphasis was on the development of wind retrieval algorithms whereas at the second most contributions were on the application of the data to oceanographic and meteorological problems. Some of the conclusions are summarised below.

Using the high resolution, all-weather capability of the sensor several examples of synoptic weather systems have been reported. Tropical cyclones have been detected clearly even when not apparent in meteorological model forecasts, presumably because of their relatively small size and inadequate observations (Figure 3). Convergence lines within the systems have also been revealed. When the scatterometer winds are assimilated into weather forecast models improvements are found, more particularly in data sparse areas, but existing model formulations do not exploit the full potential of this high-resolution dataset because it is limited to a single level in the vertical.

Efforts have also been made to construct gridded, basin-scale surface wind fields suitable for forcing ocean models. Preliminary results suggest that, because of the narrow swath of the ERS-1 scatterometer and the time it takes to build up complete coverage, temporal resolution of less than 5–7 days for such fields will not be possible. Attempts are also underway to produce fields by assimilation into atmospheric models and it will be important to compare the products resulting from the two techniques. (Improved sampling will be obtained from the ADEOS scatterometer, NSCAT, because it has a dual swath.)

For longer time scales (greater than 1 month, say) there is less of a sampling problem and investigations in both the tropics and the Southern Ocean showed that not only did the ERS-1 wind fields correspond to known climatologies but that the satellite data were revealing additional information which, if real, may be important for understanding the response of ocean circulation to meteorological forcing. In one study reported at the Hamburg Symposium monthly mean ERS-1 winds were used to force a model of the tropical Pacific and gave realistic depictions of the upper ocean response.

Some possible causes of errors in wind speeds

Erroneous winds are retrieved when sea-ice is within the footprint and must be eliminated. This sensitivity to ice cover can also be exploited to provide a means for detecting the ice edge. Comparisons with independent estimates (using passive microwave radiometer data, for example) are needed. Some evidence has been presented suggesting that winds may be severely underestimated when precipitation is present. Although this was a problem with Seasat it was expected that the effect due to atmospheric attenuation would be much less severe at the frequencies used on ERS-1. This may pose a problem when accurate winds are required for case studies of storms, where a correlation between wind and precipitation is to be expected, but may not be too serious for generating time and space-averaged wind stresses for ocean circulation studies unless the phenomena are geographically persistent, *e.g.* Inter-Tropical Convergence Zone. (It is worth noting that the altimeters on ERS-1 and TOPEX-POSEIDON also show rain-associated effects.)

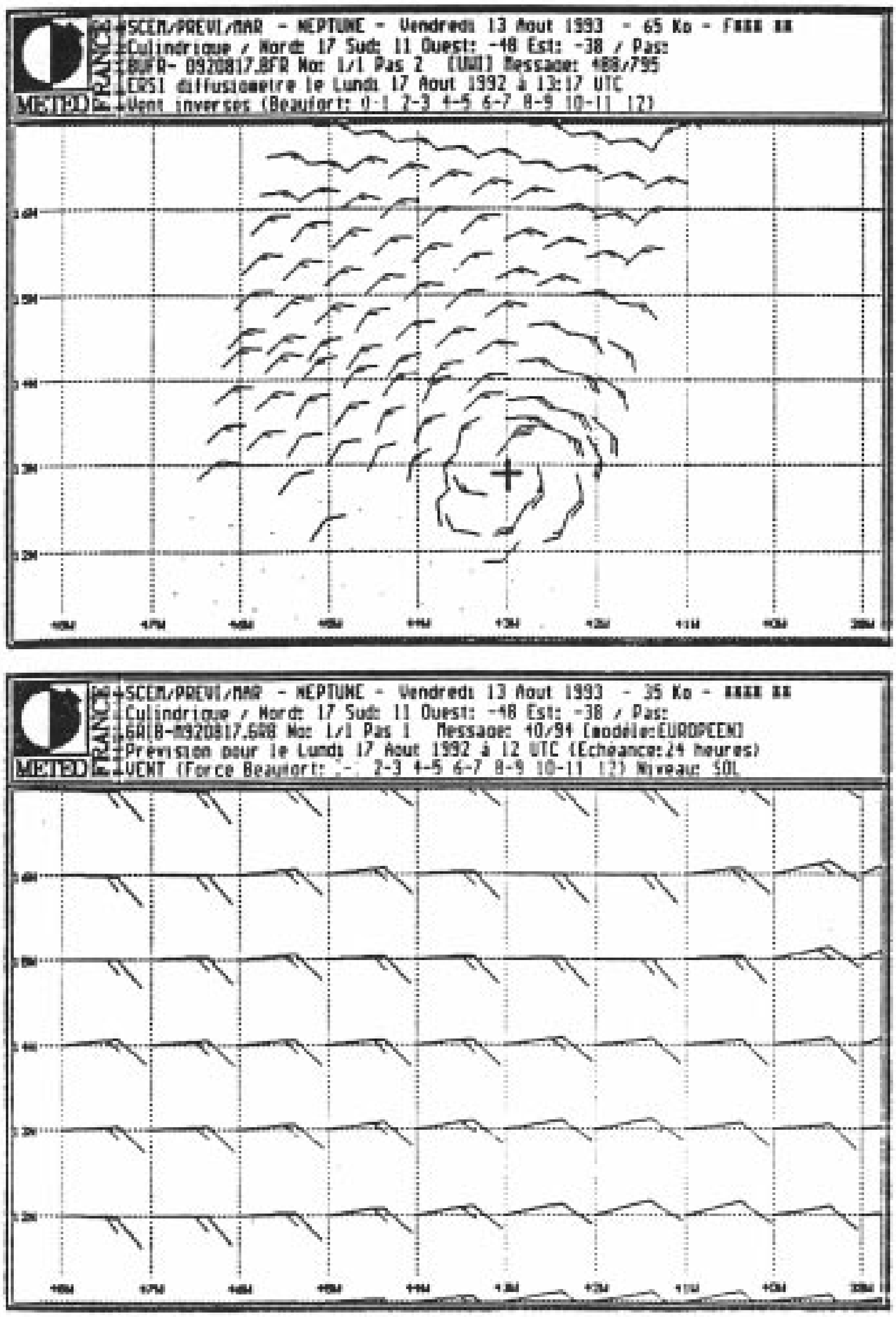

Figure 3. Winds at approximately 12Z on 17 August 1992 from ERS-1 scatterometer (upper) and ECMWF 24 hour forecast (lower). ERS-1 winds are plotted at half resolution (50 km) for clarity. The cross in the upper figure indicates the estimated location of Hurricane Andrew's centre. (From Roquet and Poitevin, pp. 1133–1126 in ESA, 1994)

Products

ERS-1 was designed to give winds in near real-time for forecasting purposes, the so-called Fast Delivery Product, and it is this which is distributed to PIs by ESA. Unlike other sensors there has been no attempt to provide an improved product for off-line distribution. IFREMER has, however, generated one which should be more suitable for oceanographic applications. It includes ECMWF analysis wind velocities as well as all the aliases giving users the option of performing their own ambiguity removal. Readers interested in this product should contact Guy Duchossois, the Mission Manager for ERS-1 and ERS-2 at ESA HQ, 8–10 rue Mario Nikis, Paris Cedex 15, France.

References

Chelton, D.B., A.M. Mestas-Nuñez, and M.H. Freilich, 1990. Global Wind Stress, Wind Stress Curl, and Sverdrup Circulation from the Seasat Scatterometer. J. Phys. Oceanogr., 20, 1175-1205

ESA, 1993. Proc. First ERS-1 Symposium: Space at the Service of our Environment, Cannes, 4–6 November 1992, ESA SP-359, 930pp.

ESA, 1994. Proc. of 2nd ERS-1 Symposium: Space at the Service of our Environment, Hamburg, 11–14 October 1993, ESA SP-361, 1355pp.

The ESTOC Time Series Station Started Operation

Octavio Llinas, Instituto Canario de Ciencias Marinas, 35200 - Telde, Gran Canaria, Spain; Argeo Rodriguez de Leon, Instituto Espanol de Oceanografia, 28020 Madrid, Spain; Gerold Siedler, Institut für Meereskunde, Universität Kiel, 24105 Kiel, Germany; and Gerold Wefer, Universität Bremen, 28334 Bremen, Germany

The WOCE Science Plan included the requirement of establishing time series stations using research vessels. The main goals were to identify secular changes in deep water masses, to provide information on the temporal evolution of temperature and salinity as a complement to hydrographic stations, and to provide comparison data for the check of accuracies of observations made from commercial ships or satellites. Similarly, the JGOFS Science Plan calls for the establishment of time series stations. Two such stations exist now, one at Bermuda and one at Hawaii, both in the interior of the respective oceans.

The Canary Islands region appeared to be an appropriate location for the establishment of a time series station in an eastern boundary regime. The archipelago in the North Atlantic is surrounded by deep water, is situated in the eastern boundary flow, and several marine research institutions exist on the islands which are able to contribute to the operations. With a long record of observations in the deep Canary Basin, the Marine Physics group at the Institut für Meereskunde (IfM) in Kiel, Germany, joined forces with the Instituto Espanol de Oceanografia (IEO), the Instituto Canario de Ciencias Marinas (ICCM) and the JGOFS group at the University of Bremen (UB) in establishing the 'European Station for Time-series in the Ocean Canary Islands' or 'Estacion Europea de Series Temporales Oceanicas de Canarias' (ESTOC).

The station position is located about 60 nautical miles to the north (upstream) of the islands of Gran Canaria and Tenerife. The goal is to occupy the station on one day each month with a research vessel. These measurements are complemented by moored observations. The backbone of the programme is the research vessel 'Taliarte' of the ICCM (length 40 m, 350 tons). From time to time other Spanish and German vessels will be available instead. Programme components are funded by the Spanish and German governments.

The 'Taliarte' will soon be equipped with another winch, A-frame and CTD/Rosette to allow WOCE-type CTD measurements. It was decided that it will be valuable to start the time series with Nansen bottle/reversing thermometer observations as early as possible in order to gain operational experience and a first view of temporal variablity at the ESTOC station. Since January 1994 the station was occupied regularly each month, usually by the Spanish 'Taliarte' and once by the German 'Poseidon'. The following parameters are being determined at this time: temperature, salinity, chlorophyll, nutrients, oxygen, some ichtioplankton and the distribution of zooplankton.

A mooring with sediment traps was repeatedly deployed at the ESTOC position by the UB group since 1991. A current meter mooring was added by the IfM group in October 1994. In addition XBT lines exist between Gran Canaria and the station and also between Gran Canaria and the African coast. It is expected that the set of observations will be extended during the first few years of operation. Survey cruises will be carried out in the region at least once per year to check the representativeness of the ESTOC data. The first of these surveys were performed by 'Poseidon' in February 1992 and October 1994.

The station work is overseen by an International ESTOC Committee with its members (the authors of this note) representing the four participating institutions, and with two members also bringing in their experience in WOCE and JGOFS, respectively.

It is hoped that the existence of the ESTOC station near the Canary Islands will lead to other programmes with participants making use of the time series data as a reference.

Dr Octavio Llinas
Instituto Canario de Ciencias Marinas
Apartado correos 56
35200 - Telde
Gran Canaria
Spain

Dr Argeo Rodriguez de Leon
Instituto Espanol de Oceanografia
Av. Brasil 31
28020 Madrid
Spain

Prof. Gerold Siedler
Institut für Meereskunde
Universität Kiel
Düsternbrooker Weg 20
24105 Kiel
Germany

Prof. Gerold Wefer
Universität Bremen
Fachbereich 5 - Geowissenschaften
Postfach 33 04 40
28334 Bremen
Germany

Euphotic Zone Nitrate Variability in the Central North Pacific Gyre at the Hawaii Ocean Time-Series Station ALOHA

Luis M. Tupas, University of Hawaii at Manoa, Honolulu, HI 96822, USA

Introduction

As part of the Hawaii Ocean Time-series (HOT) programme (Lukas, 1994), Joint Global Ocean Flux Study (JGOFS) scientists are trying to determine the annual and interannual variability of important biogeochemical parameters at the HOT oligotrophic benchmark, also known as Station ALOHA (A Long Term Oligotrophic Habitat environment). Monthly cruises to the station collect information on thermohaline structure, currents, water column chemistry, primary production and particle sedimentation and have already contributed directly to JGOFS and WOCE programme objectives. This article summarizes the results of five years of data on the concentrations of nitrate plus nitrite in the upper water column (surface to 250 metres). Over the past five years, we have observed considerable variability in upper water column nutrients which is not related to the vertical displacement of the water column density structure and would otherwise have gone unnoticed if not for the long-term measurement strategy employed.

Methods

Water samples are collected in polyvinyl chloride sampling bottles manufactured by the Scripps Institution of Oceanography, attached to a CTD-rosette package. Nutrient samples are routinely collected during a CTD cast to the near bottom of the water column (approximately 4800 m) and several casts to 1000 metres to define finer structural characteristics in the upper water column. Water samples were stored frozen in high-density polyethylene bottles. An analytical justification for freezing as a method of nutrient preservation is presented elsewhere (Dore *et al.*, 1994). Analysis of nitrate plus nitrite is made on a Technicon Autoanalyzer II continuous flow system using slight

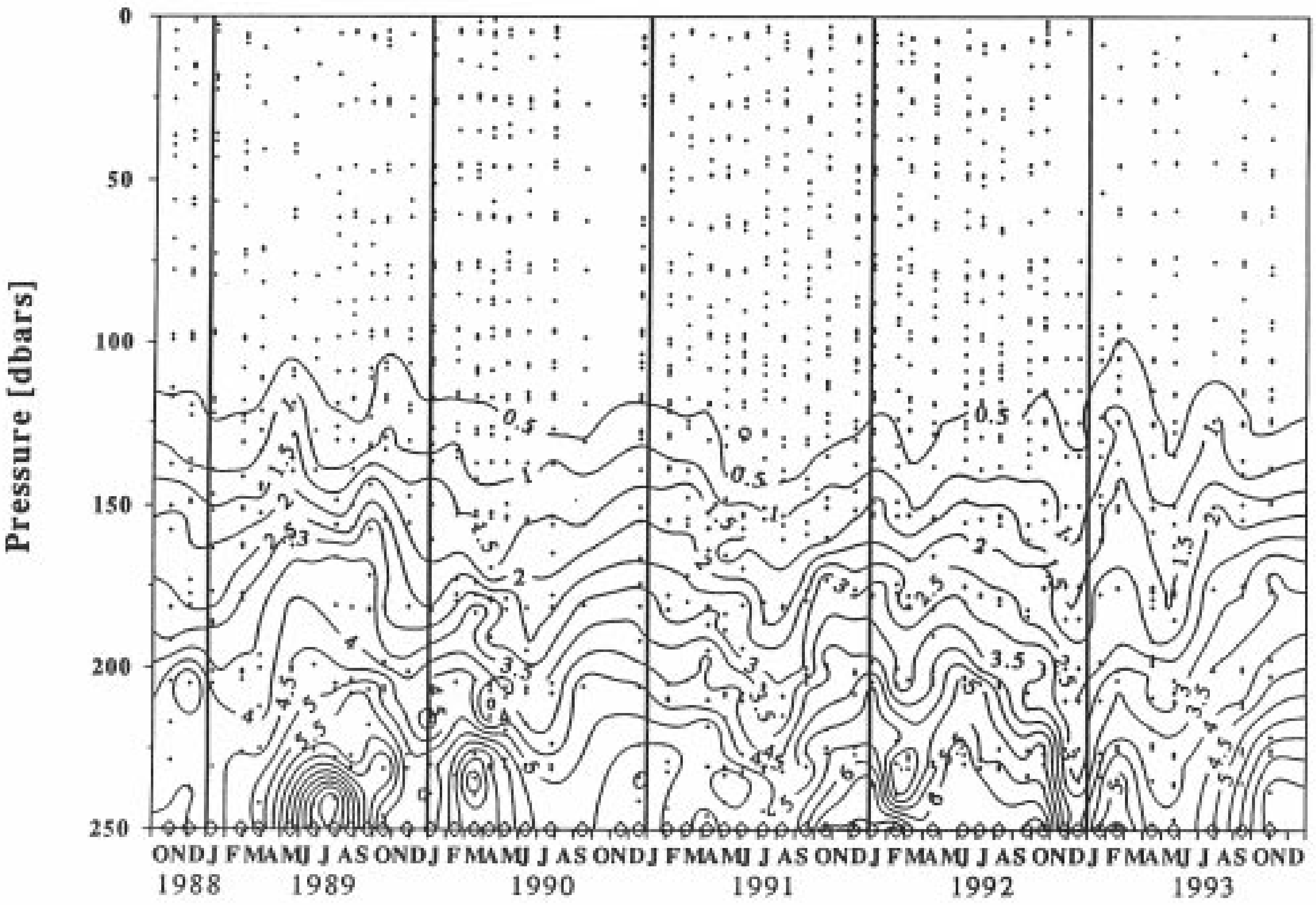

Figure 1. Contour plot of nitrate plus nitrite concentrations from the surface to 250 metres from 1988 to 1993. Dots indicate the location of water sample.

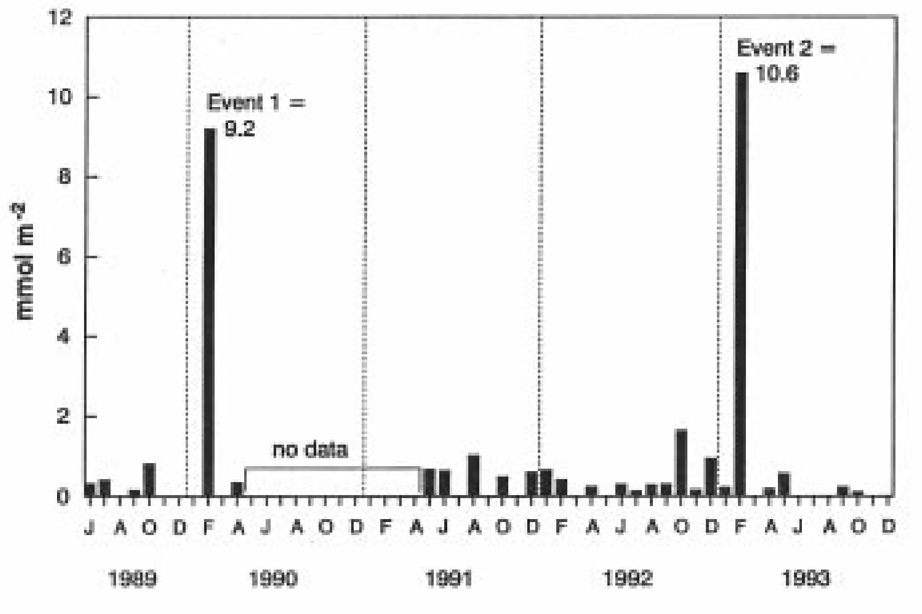

Figure 2. Depth integrated concentrations of nitrate plus nitrite from the surface to 100 metres from 1988 to 1993.

modifications of the Technicon procedures for analyzing seawater. The basic methodology was derived from Armstrong *et al.* (1967).

Results

Inorganic nutrient concentrations (nitrate plus nitrite, phosphate and silica) spanning the whole water column over the past five years of the HOT programme are available in the annual data reports and in a data base on a Sun workstation at the University of Hawaii accessed through the Internet by anonymous ftp or the World Wide Web (*e.g.* Mosaic at http: //hahana.soest.hawaii.edu). This article, however, focuses on the euphotic zone where micro-biological and biogeochemical dynamics is of greater importance in the flux of energy and materials. Nitrate-nitrogen is of particular interest because it is only supplied by advection and turbulence from deeper waters and is the basis for what is referred to as new production in the ocean (Eppley and Peterson, 1979).

The base of the euphotic zone at Station ALOHA, defined as the depth where the light level is 0.05% of the surface photosynthetically available radiation (PAR), is at about 175 metres. The deep chlorophyll maximum layer is located at about 110 metres while primary production is greatest at the upper 45 metres of the water column.

Figure 1 shows a time-series contour of nitrate plus nitrite concentrations in the upper 250 metres of the water column. A few events showing nitrate injections to the upper water column were observed during the spring of 1989 and the winter of January 1992 and 1993 and smaller events in the spring of 1990 and 1991. Above 100 metres, the concentrations range from 0.01 to 0.10 μmol kg^{-1}. These concentrations approach the limit of detection for standard autoanalyzer methods.

Using a sensitive chemiluminescence technique that can detect nitrate plus nitrite as low as 2 nmol kg^{-1} (Garside, 1982), a more accurate measurement of their concentrations was made. Figure 2 shows the integrated concentration of nitrate plus nitrite for the upper 100 metres of the water column. Above 100 metres evidence of nitrate plus nitrite injections were observed on two occasions. These injections may be so randomly spaced that they could be occurring more often than what we have observed.

Figure 3 shows the calculated mixed layer and nitricline (an estimate of where nitrate begins to appear in the water column) depth during each period of observation. The mixed layer depth was calculated as the depth where the density was 0.125 σ_t units different from surface density (Levitus, 1982). The nitricline depth was determined by making a linear regression between nitrate concentration and depth, using only the values of nitrate from 0.4 μmole kg^{-1} to the concentration at 200 metres, and extrapolating the regression line to a concentration of zero on the depth axis.

Both mixed layer depth and nitricline depth vary with time but without any distinct temporal pattern or coherence with each other. The mixed layer depth reflects the seasonal heating and cooling of the upper water column. There appears, however, to be a noticeable difference in the average depth and magnitude of variation of these parameters from January 1991. From October 1988 to December 1990, the average nitricline depth was 101 metres (standard deviation 21 metres) and mixed layer depth was 58 metres (standard deviation 26 metres). January 1991 to December 1993, the average nitricline depth was 114 metres (standard deviation 19 metres and mixed layer depth was 47 metres (standard deviation 17 metres). This is evidence of a significant change in the Central North Pacific Gyre ecosystem which HOT-JGOFS scientists are attributing to the 1991–1993 El Niño Southern Oscillation (ENSO) phenomena (Karl *et al*., 1994).

Discussion

The location of Station ALOHA was based on several scientific as well as logistical criteria (Karl and Winn, 1991). Based on historical studies of the region, Station ALOHA is quite representative of the Central North Pacific

Gyre ecosystem. Nutrient observations at the study site show the typical nutrient-starved conditions of the oligotrophic open ocean. Surprisingly, primary production rates are highest in the water column where there is constant depletion of inorganic nutrients. This shows that the vertical nutrient flux is not the primary source of nutrition for autotrophic organisms and points towards the importance of recycled nutrients in sustaining their growth.

The observed discrepancy between nitrogen demand and input into the euphotic zone is most likely the result of non-steady state injections of the various forms of nitrogen. Periodically, nitrate gets injected into the euphotic zone from below but they may occur sporadically such that our quasi-monthly sampling is not sufficient to detect this. Other potential sources of nitrogen are direct atmospheric inputs and nitrogen fixation. The variable flux of nitrogen into the euphotic zone would consequently affect the spatial and temporal distribution of micro-organisms and their production.

Time-series programmes such as HOT are invaluable resources of information in describing a large ecosystem and how it functions using a multi-disciplinary approach. This is important in modeling and predicting cause-and-effect relationships on a global scale. Data from the HOT programme has shown that the oligotrophic oceanic environment experiences low frequency temporal variability in physical and biogeochemical parameters which would be unnoticed by conventional, single-point, single-time studies. Time-series studies are actually more suitable in determining the natural dynamics brought about by a combination of physical, chemical and biological effects.

The HOT programme is continuing its observations at Station ALOHA for another five years and is expected to be in operation into the next century. The past five years has been devoted to establishing a sampling strategy to build a comprehensive data base. Efforts are now focused towards distilling these observations and formulating testable hypothesis which will improve our description and understanding of the oceanic environment and develop the ability to predict environmental change arising from natural and man-made phenomena.

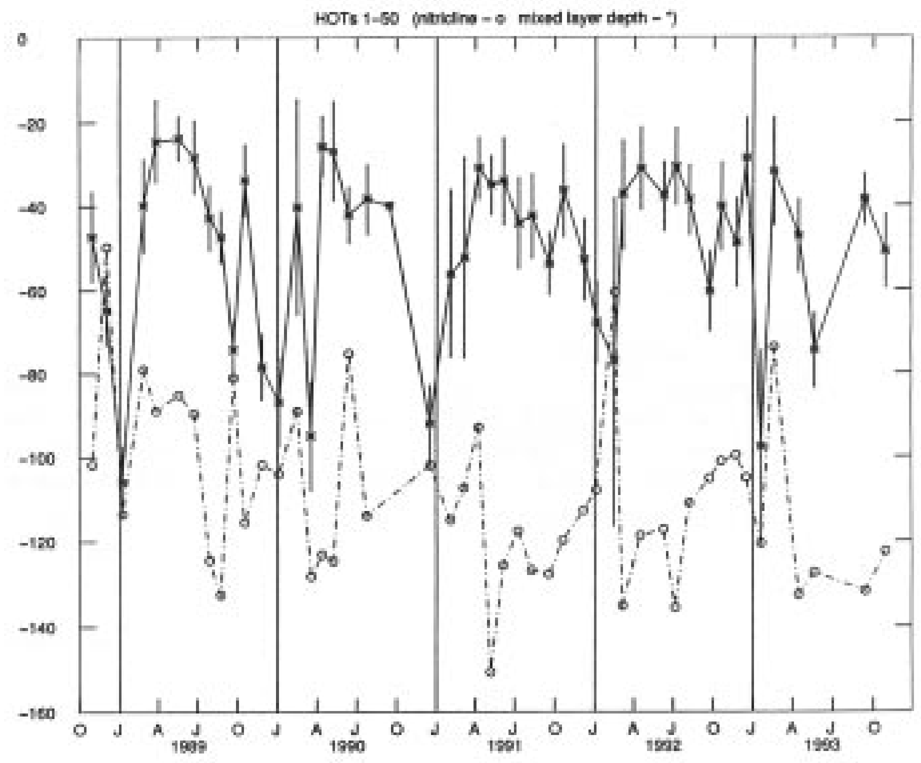

Figure 3. Calculated depths of the mixed layer, shown as the mean and standard deviation from 18–20 CTD casts, and the nitricline calculated from the measurements of nitrate plus nitrite from a single cast.

References

Armstrong, F.A.J., C.R. Stearns and J.D.H. Strickland, 1967. The measurement of upwellling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment. Deep-Sea Research, 14, 381–389.

Dore, J., T. Houlihan, G. Tien, D. Hebel, L. Tupas and D. Karl, 1994. Freezing as method of preserving seawater for inorganic nutrient analysis. Submitted to Marine Chemistry.

Eppley, R.W., and B.J. Peterson, 1979. Particulate organic matter flux and new production in the deep ocean. Nature, 282, 677–680.

Garside, C., 1982. A chemiluminescent technique for the determination of nanomolar concentrations of nitrate and nitrite in seawater. Marine Chemistry, 11, 159–167.

Karl, D.M., and C.D. Winn, 1991. A sea of change: Monitoring the ocean's carbon cycle. Environmental Science and Technology, 25, 1976–1981.

Karl, D.M., R. Letelier, D. Hebel, L. Tupas, J. Dore, J. Christian and C. Winn, 1994. Ecosystem changes in the central North Pacific gyre attributed to the 1991–92 El Niño. Submitted to Nature.

Levitus, S., 1982. Climatological atlas of the world ocean. NOAA, Maryland.

Lukas, R., 1994. HOT results show interannual variability of Pacific deep and bottom waters. WOCE Notes, Vol. 6, No. 2.

WOCE-NEG at Los Alamos

David Webb, Institute of Oceanographic Sciences Deacon Laboratory, Wormley, Surrey, GU8 5UB, UK

The 1994 Workshop and 9th Committee Meeting of the WOCE Numerical Experimentation Group (NEG) was held between the 19th and 21st September at the Los Alamos Laboratory, New Mexico. Following the 1992 and 1993 workshops on data assimilation and ocean models for climate research, the 1994 meeting concentrated on process models and the use of parallel computers for ocean research.

The Los Alamos venue was appropriate because in recent years the Laboratory has become closely involved with environmental research. In particular it has used its powerful computing facility to run a one-sixth degree version of Semtner's global ocean model.

Day one

The first day of the workshop, organised by Bert Semtner, concentrated on the 'Application of parallel computing to the solution of large scale ocean problems'. Although the new parallel computers have yet to reach their full potential, it is expected that eventually they will be used for most large scale ocean and climate models.

Richard Smith, David Webb, David Stevens, Dale Haidvogel and Reiner Bleck all gave talks on the development of parallel processor versions of ocean models. The physics contained within such models is the same as in their standard versions. However the way the calculation is organised differs, with the models splitting the ocean into small areas and allocating one processor to each. A fast message passing system sends information on the boundary points from one processor to another.

Parallel versions of the Semtner, MOM (Modular Ocean Model), isopycnal and sigma co-ordinate models are under development. In many cases they are already running and should soon be available for general release.

Richard Smith also reported on the $^1/_6$ degree global model run which has been carried out at Los Alamos. The results from this are now available for use by other experimental and theoretical oceanographers. Other speakers included Yi Chao on the use of global models with satellite altimetry, Andrew Bennett on an inverse model of global ocean tides, and Bob Chervin on modelling tracers with a parallel computer.

Day two

The second day of the workshop, organised by Bernard Barnier, was concerned more with the development of process models. Now that models resolving the oceanic Rossby radius are in regular use, further development of model realism will depend on improved representation of the sub-gridscale processes.

The morning session was on convection, mixing and flow instabilities. It included talks by John Marshall and Oscar Alves on the modelling of deep convection and talks by Eric Chassignet, Gokhan Danabasoglu and Roland de Szoeke on diffusion in the ocean. The afternoon session was concerned with Gyre dynamics and intergyre exchanges. Peter Killworth and Rüdiger Gerdes gave talks on the overflow problem, Jacques Verron discussed the separation of western boundary currents and Yan-Li Jia presented the results from a high resolution isopycnic model.

Finally Tom Rossby discussed the exchanges between subtropical and subpolar gyres, and Zhengyu Liu the exchanges between the tropics and sub-tropics. The workshop concluded with a review by Carl Wunsch on the 'Challenge of the global combination of models and observations'.

Day three

The morning of day three was taken up by a meeting of the NEG committee concerned primarily with the future developments in WOCE, the plans for the assimilation of WOCE data into models and the relationship with CLIVAR. Over the next few years the NEG expects to be even more closely involved with the problems of WOCE data assimilation.

The committee was concerned about how few plans there were for WOCE data assimilation and the difficulty in deciding how best to proceed. Should there be a precise product definition and should this be global? How much were we limited by gaps in the WOCE data set and how much by the limits in available computer power? Can error fields be given?

The estimation methods are still at the development stage, so it is likely that the first efforts at WOCE data assimilation will be tentative. On the other hand progress is likely to be most rapid if we aim now for a 'definitive WOCE analysis'. In any case the committee felt that the WOCE problems were not widely appreciated by the ocean data assimilation community and that there was much work still to be done.

A detailed report of NEG-9 and the workshop, including abstracts of the presentations, will be published by the IPO as No. 125/94 in the WOCE Report Series.

Summary of WOCE Hydrographic Programme Planning Committee Meeting

James Swift, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0214, USA

The thirteenth meeting of the WOCE Hydrographic Programme Planning Committee (WHP-13) was held 2–4 November 1994 at the College of Marine Sciences, National Sun Yat-Sen University, Kaohsiung, Taiwan, Republic of China.

The new organizational structure for WOCE met with generally favourable comment by the PC.

In trying to speed up the availability of data to WOCE researchers the PC recommended that when two-year-old preliminary data are held by the WHP Office that the WHPO write to the Chief Scientist seeking explicit permission to transfer the data to the SAC for inclusion in the new ftp directory of preliminary data. In the case of data regarded to be final, the PC also supported seeking Chief Scientists' permission to make the data available for release. The PC believes that the requirement to obtain this permission will, on its own, be a sufficient safeguard of the special interests of specific investigators or countries.

Terry Joyce (Director WHPO) made an offer to South Atlantic PIs to create a restricted-access ftp site for South Atlantic WHP data. However, PI response to the letter proposing this action has so far been insufficient to warrant further WHPO preparations for such a programme. (The logical conclusion is that WOCE scientists do not want to share data!) The PC agreed that the WHPO should support US Indian Ocean proposal for data sharing (with an ftp site and some related services), and to offer the service to the entire Indian Ocean WHP community.

The PC proposed that the SSG should ask the International Group of Funding Agencies for Global Change Research to consider that WHP/SAC data sharing resources be provided to all countries contributing releasable WHP data.

Line P9 (Japan to New Guinea, on 137°E), the highest-priority gap in one-time survey coverage identified earlier by Core Project 1, has been satisfactorily carried out by Japan. The Republic of China offered to provide ship and CTD services in 1996 for a WHP programme on line P26 (Taiwan to 137°E, on 22°N – by a one time extension of their PR20 repeat work to the P9 line), the second highest priority gap in coverage. WOCE organizations are asked to work together to help coordinate contributions to bring the work to one-time survey standards.

WHP SAC data listings will soon be brought up to date with implementation of a data retrieval system which tracks and retrieves versions of data. The WHPO has established a rudimentary "home page" on Mosaic, and links to other WHP sites will soon be provided.

The PC reviewed the WHP Special Analysis Centre (SAC) work on a reference data set for the South Atlantic, and decided that a small amount of restructuring of the work could soon lead to a set of tools that various WOCE or non-WOCE data sets can be fed into to produce gridded fields for comparisons.

Although within the last 6 months there has been a substantial decline in the performance of the Data Quality Evaluators (mostly tardy DQE reports), there is no support within the WHP investigators or the PC for disbanding the DQE process as presently constituted.

The PC approved the recommendations of the May 1994 WHP Data Meeting. The PC noted that the DPC is clearly given the responsibility for WOCE scientific oversight of WHP data archival. Terry Joyce will remain the WHP liaison with WDC-A and the DPC. Regarding the proposal from the WOCE Data Products Committee to establish an ADCP data archive at JODC, the PC approved using the WHPO as a conduit for data submission.

There has not yet been implementation of the WOCE parts of the US JGOFS CO_2 data management system as outlined in the US JGOFS newsletter. The PC urged the full implementation of the plan with minor changes suggested at WHP-13.

The concept of the WHP Atlas met with general approval. However, there are at present no SAC resources to apply to such an effort. The SAC was directed to investigate, on a time-available basis, support for a Mosaic "browser" for standard data products and maps, should any become available.

WOCE Flow Statistics: A Call for Contributions

In 1989 a compilation of world-wide flow statistics from long-term current-meter records was made to provide the fullest possible set of flow statistics for use in model validation and development (Dickson, 1989, Flow Statistics from Long-term Current Meter Moorings: The Global Data-set in January 1989. WCRP-30 WMO/TD 337, WOCE Report No.46/90). It includes all available pre-WOCE moorings (2369 instrument-years of records). A second compilation is underway in which it is hoped to include all moorings since 1989 (around 1500 WOCE records). We request from WOCE participants statistics of eddy kinetic energy and the kinetic energy of the mean flow per unit mass, and eddy momentum flux if available, derived from low-passed, long-term (>9-month) deep ocean records (depths >500m), with mooring details (location, duration, water and instrument depths etc.), and a figure of the mooring and suurounding bathymetry. Data should be sent to Bob Dickson at the MAFF Fisheries Laboratory, Lowestoft, UK, NR33 OHT (R.R.Dickson@dfr.maff.gov.uk). All sources will be fully acknowledged in the report.

The South Atlantic: Present and Past Circulation

Gerold Siedler, Institut für Meereskunde, Düsternbrooker Weg 20, 24105 Kiel, Germany

The first WOCE science meeting for the South Atlantic was held at Bremen University, Germany, from 15 to 18 August 1994. Because of recent major WOCE and also paleoceanographic activities in this part of the global ocean, the meeting was carried out as an interdisciplinary symposium aimed at the understanding of the present (WOCE) and the past (paleo) oceanic circulation. About 220 physical and chemical oceanographers, tracer physicists, geologists and geochemists from Europe, the USA, Africa and South America met to present and discuss new results. The initiators of the meeting were Gerold Wefer of the Geosciences Department of Bremen University and Gerold Siedler of the Institut für Meereskunde at Kiel University. The symposium was co-sponsored by WOCE, the Oceanography Society and the Scientific Committee on Oceanic Research (SCOR), and was partially funded by the Deutsche Forschungsgemeinschaft (DFG) and the State Government of Bremen. An international Scientific Committee decided on the format of the meeting and the selection of convenors and invited speakers. Barbara Donner of Bremen University was responsible for local arrangements.

The symposium had four themes:

(1) the South Atlantic as a gateway of the thermohaline circulation,

(2) the circulation and water masses of the South Atlantic and their imprint on sediments,

(3) boundary currents and upwelling and

(4) the heat, fresh water, carbon and nutrient budgets.

A wealth of new data was available. All the zonal WOCE WHP sections between the equator and the Circumpolar Current regime had been completed by mid-1994, and a large amount of ocean current data from moorings, floats and Argos drifters had been collected in the Brazil Basin and its boundary regions during WOCE cruises. New data from bottom sediments provided information on the strength of the intermediate and deep waters and their pathways during geological time scales.

The format of the meeting was chosen in a way which ensured a close interaction of scientists from the various disciplines. Results were presented in about 40 lectures and more than 140 posters. Topics from physical oceanography and paleoceanography were deliberately mixed in oral and poster presentations, without any parallel sessions. Lectures were given in the mornings, and 3 hours were specifically reserved in the afternoons for disciplinary and inter-disciplinary discussions at the posters. Most days ended with an evening lecture on a general topic: on the South Atlantic's role in the global circulation (A.L. Gordon), on the competition between the southern and northern hemispheres in driving the global ocean circulation (J.C. Duplessy) and on paleochemical tracers of the glacial maximum South Atlantic circulation (E. Boyle).

The symposium greatly helped to accelerate the analysis of WOCE data. The interaction of scientists from different disciplines and between observers and modellers during the sessions and also outside the sessions was regarded a great success by the participants.

An abstract volume was available at the meeting (Symposium - The South Atlantic: Present and Past Circulation, Bremen, 15–19 August 1994. Abstracts. Berichte, Fachbereich Geowissenschaften, Universität Bremen, No. 52, 167 pp., Bremen 1994). Survey articles and key results from the symposium will be published as a book. The review process for several chapters is already underway.

The WOCE Current Meter Data Assembly Center

Dale Pillsbury, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331-5503, USA

Oregon State University (OSU), College of Oceanic and Atmospheric Sciences, houses the WOCE Current Meter Data Assembly Center (CMDAC).

The CMDAC is primarily responsible for tracking the WOCE current meter data collection efforts, receiving the quality-controlled data sets and ensuring that these data sets contain all the necessary installation, recovery, and calibration information. At the appropriate time, the DAC will forward the data sets to NODC for archiving and distribution. In addition to its primary task the CMDAC was asked to assemble a uniformly processed, high-quality set of current meter records collected prior to the WOCE observing period. These historical records were considered of potential interest to WOCE scientists if they were from water deeper than 200 metres and longer than nine months. In the past two years the Center has collected about 1,300 records which meet this screening criteria. Users of the database are encouraged to examine this data set and suggest additional data which are not included.

WOCE-collected data have been slow to arrive at the

DAC. Principal investigators are encouraged to submit their data as soon as possible. In some cases the DAC has been able to point out problems with the data to the PIs which have been helpful. In other cases we have been able to request missing metadata before these have been lost or filed obscurely. The DAC considers itself a partner with the PI helping to ensure that WOCE produces the highest quality data possible.

All of the WOCE-collected data which have been submitted have been placed in the database. For almost all of these data the access is restricted because the propriety period has not passed. The WOCE Data Handbook provides a summary (February 1994) of the WOCE current meter mooring array status. A new version of the Data Handbook will be available soon. A printed version of the current catalogue of holdings will sent by the DAC upon request. As mentioned above there are some 1,300 historical records available for full use.

The CMDAC provides remote users access to the database via dial-up phone lines or the internet. Contact the DAC providers using the addresses given at the end of this article or refer to the WOCE Data Handbook for explicit instructions for use. Users who log on will be lead to search using a map of the globe that can be expanded for the region of interest until each individual mooring can be seen. The North Atlantic holdings are shown in Figure 1. After selecting specific data for examination, the user can look at statistics for the individual records, make and print real time plots of any of the variables, make and print spectra, filter the data to remove tides or other dominant periodic fluctuations, and finally either download the data selected automatically via the network or request files on alternative media.

The CMDAC maintains both the original current meter records, as supplied by the PI, and any versions that may have been modified for standardization and quality control. Both versions are available. Full credit for the investigator will be given as a part of the data transfer when data which are in the public domain are issued, and no data which are not declared by the PI to be in the public domain will be issued without written permission of the PI.

A Mosaic Home Page is under construction to offer an alternate interface to the database. It is intended that Mosaic will provide an easy-to-use and common interface for all of the DACs. An issue being addressed at OSU now is whether Mosaic software will allow the dynamic production of data products or only static products with predetermined formats. In either event the home page will allow the user to access the original interface which does provide dynamic use of the database.

At the last meeting of the Data Product Committee (DPC-7) the subject of “data orphans” was discussed (see article in this issue) and from now on the CMDAC will handle some of the recognized orphans. These are data from moored ADCP if they were located in a designated WOCE current meter experiment and hydrographic data taken as a part of calibration casts or installation or recovery casts for mooring efforts. In addition the DAC will add pressure gauge mooring data to the data base.

The DAC provides access to data from long current meter deployments. Such data can be used (a) as input for diagnostic or data assimilation models; (b) in validation of numerical ocean models; (c) in the planning of regional studies, process studies, and moorings to monitor specific currents or processes; and (d) in standard time series or statistical analyses. The CMDAC facilitates such studies by providing a uniformly processed base of the highest quality data available, in an interactive environment.

For information contact Joseph Bottero or Dale Pillsbury at Oregon State University ((503)-737-350; bottero@oce.orst.edu) or ((503) 737-2207; pillsbury@oce.orst.edu) fax (503) 737-2064.

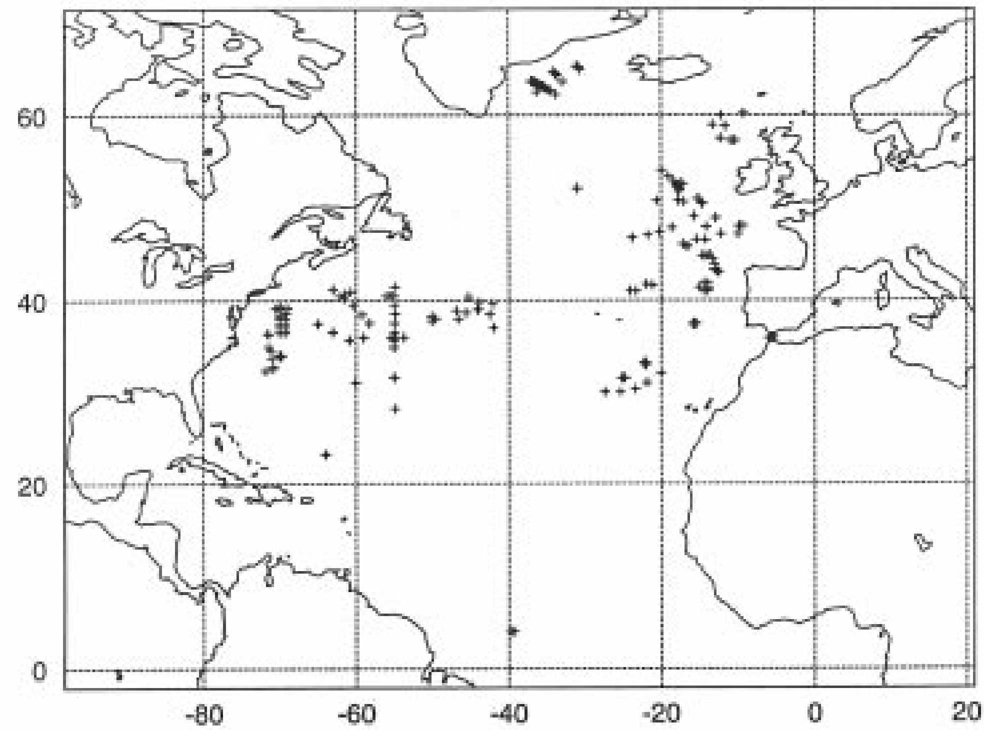

Figure 1. Location of North Atlantic current meter data available at the CMDAC. This map comes up by using the graphical interface of the CMDAC. The user can select particular records by using the mouse to draw a box around them on the map.

WOCE Data Flow and the WOCE Data Products Committee

N. Penny Holliday and Andrea Frische, WOCE IPO, Wormley, UK

WOCE is well over halfway through its observational programme. Most of the Pacific programme is completed. Much of the Southern Ocean and South Atlantic programmes are either underway or complete. The North Atlantic has seen a lot of activities which will intensify 1996–1997. Plans for the Indian Ocean activity are complete with a programme set to commence in 1995.

After almost 5 years of intensive observations, the WOCE field programme has generated a large number of complete individual datasets and an assembly and delivery system is now in place for most WOCE data types. The emphasis within WOCE now goes beyond a series of individual sections or projects towards the collation of datasets and generation of data products for wider reaching analyses (multiple parameter, basin-wide, or long term change). The data system has been developed to ensure individual datasets are available for researchers aiming to understand the ocean circulation as a whole.

The data flow is from the principal investigators (PI) into the Data Assembly Centres (DACs), then to Special Analysis Centres (SACs), and ultimately out to the researchers again. To achieve maximum benefit the data flow has to be quick; unfortunately some are taking far longer than it was planned.

Speeding up Data Flow

In May 1994 the WOCE Hydrographic Programme (WHP) Planning Committee (PC) held a data meeting in Arlington to address how to speed up WHP data flow, and to consider the requirements for a WHP repository (archive) at the World Data Centre (WDC).

To streamline the Data Quality Evaluation (DQE) process for hydrographic data, it was agreed that when a DQE report is completed and the conclusions passed to the chief scientist, the data originators will be advised that they have a certain time period in which to respond, after which the DQE report will be implemented within the WHP Office. Further, it was suggested that WOCE hydrographic data older than 2 years be released, even if the DQE process is not complete. This should only be done after the chief scientist's approval has been obtained, in accordance with the policy that for all WOCE data types (except real-time data) permission must be obtained from the data originators before general release.

The WHPPC is also encouraging the PIs to form collaborative projects with scientist from the modelling and satellite communities as well as other observationalists who wish to analyse WHP data before the 2 year time period is over.

Initiative was taken by the WHPPC to start the implementation of an on-line searchable catalogue of WHP data to be developed at WDC-A by setting up a list of keywords. At its 7th meeting in September 1994 the Data Products Committee (DPC) asked all DACs to list the search attributes they think are necessary for a catalogue and retrieval system satisfying their particular data type. In the future, users would then be able to request data through the catalogue. The development of the WOCE archive at WDC-A will be a co-operative effort between the WDC-A, the DACs, SACs, and the scientific community.

DPC-7

The DPC-7 meeting was the first one after the change from the former Data Management Committee (DMC) to the new Data Products Committee. The change in name gives expression to wider responsibilities, reflecting the move towards data analyses and syntheses within WOCE.

The slow data flow was on their agenda too. Beside the above recommendations from the WHPPC it was suggested that the DACs offer data handling and viewing tools (software) to the PIs, thereby helping them to submit their data in time. The Current Meter DAC (CMDAC) is already providing such tools. Another possibility to help speeding up the data flow are post-cruise data meetings. All participants agreed that cooperation on an interpersonal level is essential, to keep the train running.

Over recent years different kinds of ADCP data have accumulated for which no DACs or SACs had been identified, so-called 'data orphans'. Data from moored ADCPs and hydrographic data collected on current meter mooring cruises will now be collected by the CMDAC (see article in this issue). The underway ADCP data will eventually go to a DAC; investigations are underway to locate a suitable centre. The fate of lowered ADCP data is still not clear, it will be an issue for the next DPC meeting.

Several WOCE DACs, SACs as well as the Data Information Unit (DIU), IPO etc. now have MOSAIC homepages for those with access to the World Wide Web (WWW). The WWW is rapidly becoming a mechanism for disseminating data and information about WOCE and the DPC has asked all DACs to set up a site with data catalogues and static browse products. For details on the DIU and how to use the on-line Gopher and WWW Information Systems see Newsletter 16.

Detailed reports on the above meetings are published by the IPO in the WOCE Report Series. The reference numbers are 122/94 (WHPPC Data Meeting) and 124/94 (DPC-7).

The following is a list of addresses of the different Data Assembly Centres, the Special Analyses Centre as well as the Data Information Unit and the WHP Office, which can be contacted for information and data. Many of these Centres have information and data on the World Wide Web (WWW). If you have WWW browsing software on your computer (such as Mosaic), use the Uniform Resource Locator (URL) and the addresses given below. How to do this varies with different software, but for example, with Mosaic, select File/Open URL and enter the address at the prompt. All the DACs and SACs can be accessed from the DIU OCEANIC page which also has links to many other oceanographic data sources. The WOCE IPO has a page at http://www.nwo.ac.uk/iosdl/Others/woceipo/ipo.html.

DIU	**WHP Office**
Katherine Bouton College of Marine Studies University of Delaware Lewes, DE 19958 USA Tel: 1-302-645-4278 Fax: 1-302-645-4007 Internet: bouton@delocn.udel.edu WWW: http://www.cms.udel.edu/	Terry Joyce Director, WOCE Hydrographic Programme Office Woods Hole Oceanographic Institution Woods Hole, MA 02543 USA Tel: 1-508-457-2000 x2530 Fax: 1-508-457-2165 Internet: whpo@whpvax.whoi.edu WWW: http://whpo.whoi.edu/

SACs

WHP-SAC	**Surface Fluxes**
Kai Jancke M53/DOD Bundesamt für Seeschiffahrt und Hydrographie PO Box 30 12 20 D-20305 Hamburg Germany Tel: 49-40-3190-3538 Fax: 49-40-3190-5000 Internet: kai.jancke@m5.bsh.hamburg.d400.de WWW: http://www.dkrz.de/~u241046/	**David Legler** Center for Ocean-Atmosphere Prediction Studies Florida State University Room 020 Love Bldg. Tallahassee, FL 32306-3041 USA Tel: 1-904-644-3797 Fax: 1-904-644-4841 Internet: legler@coaps.fsu.edu WWW: gopher://diu.cms.udel.edu/11/woce_diu/datadirs/FSU

DACs

Upper Ocean Thermal (XBT)		
Real Time (Inflexion Point)	**Real Time and Delayed Mode**	**Delayed Mode (High Resolution)**
Ron Wilson Director, MEDS Department of Fisheries and Oceans 1202 200 Kent Street Ottawa, Ontario Canada K1A 0E6 Tel: 1-613-990-0264 Fax: 1-613-990-5510 Internet: wilson@ottmed.meds.dfo.ca	Bruce Douglas Director, NODC NOAA 1825 Connecticut Ave NW, Rm 406 Washington, DC 20235 USA Tel: 1-202-606-4594 Fax: 1-202-606-4586 Internet: bdouglas@nodc.noaa.gov WWW: http://www.nodc.noaa.gov/index.html	Jean-Paul Rebert Global Subsurface Data Center IFREMER/ORSTOM BP 70 29280 Plouzané France Tel: 33-98-22-45-13 Fax: 33-98-22-45-14 Internet: rebert@orstom.fr

DACs

Current Meter	Float	Drifter
Dale Pillsbury College of Oceanography Oregon State University Oceanography Admin Bldg 104 Corvallis, OR 97331-5503 USA Tel: 1-503-737-2207 Fax: 1-503-737-2064 Internet: pillsbury@oce.orst.edu WWW: http://tethys.oce.orst.edu/cmdac.html	Philip Richardson Department of Physical Oceanography Woods Hole Oceanographic Institution Woods Hole, MA 02543 USA Tel: 1-508-457-2000 x2546 Fax: 1-508-457-2181 Internet: prichardson@whoi.edu WWW: gopher://gopher.whoi.edu/11/WHOI-databases/sub-surface.float	Ron Wilson Director, MEDS Department of Fisheries and Oceans 1202 200 Kent Street Ottawa, Ontario Canada K1A 0E6 Tel: 1-613-990-0264 Fax: 1-613-990-5510 Internet: wilson@ottmed.meds.dfo.ca
WHP	**Surface Temperature and Salinity**	**Surface Meteorology**
Terry Joyce Director, WOCE Hydrographic Programme Office Woods Hole Oceanographic Institution Woods Hole, MA 02543 USA Tel: 1-508-457-2000 x2530 Fax: 1-508-457-2165 Internet: whpo@whpvax.whoi.edu WWW: http://whpo.whoi.edu/whpo/	Alain Dessier Global Subsurface Data Centre IFREMER/ORSTOM BP 70 29280 Plouzané France Tel: 33-98-22-45-07 Fax: 33-98-22-45-14 Internet: dessier@orstom.fr	David Legler Center for Ocean-Atmosphere Prediction Studies Florida State University Room 020 Love Bldg. Tallahassee, FL 32306-3041 USA Tel: 1-904-644-3797 Fax: 1-904-644-4841 Internet: legler@coaps.fsu.edu WWW: ftp://masig.ocean.fsu.edu/pub/WOCE
Bathymetry	**Sea Level**	
	Fast Delivery	**Delayed Mode**
Robin Warnken National Geophysical Data Center NOAA Mail Code E/GC3 325 Broadway Boulder, CO 80303-3328 USA Tel: 1-303-497-6448 Fax: 1-303-497-6513 Internet: rrw@mail.ngdc.noaa.gov WWW: http://www.ngdc.noaa.gov/mgg/geodas/geodas.html	Gary Mitchum UH Sea Level Center University of Hawaii 1000 Pope Road Honolulu, HI 96822-2336 USA Tel: 1-808-956-6161 Fax: 1-808-956-2352 Internet: mitchum@lolo.soest.hawaii.edu WWW: ftp://kia.soest.hawaii.edu/	Lesley Rickards BODC Proudman Oceanographic Laboratory Bidston Observatory Bidston, Birkenhead Merseyside L43 7RA UK Tel: 44-51-653-8633 Fax: 44-51-652-3950 Internet: bodcmail@unixa.nerc-bidston.ac.uk WWW: ftp://bisag.nbi.ac.uk/pub/

Note from the WHP-SAC: Inaccessibility of DKRZ

About four months ago, the Deutsche Klimarechenzentrum (DKRZ) introduced a separate machine as an info-server. This machine kept the IP number of the old server: 136.172.110.11. Its logical name is now **ftp.dkrz.de**. Some people might still use old logical names like “prince.dkrz.de” or “x.dkrz-hamburg.de.” DKRZ logs still show some request for connections to machines using very old names. Please take note of the new name of the server holding WHP data and DO NOT use the old names any more.

The NODC Ocean Bulletin Board Service

The National Oceanographic Data Center (NODC) is pleased to announce the creation of an Ocean Bulletin Board Service (BBS) to promote communication among the oceanographic community. This new bulletin board was implemented using tools and resources of the Internet. Every effort will be made to keep it simple to use. Users of the NODC Ocean BBS will be able to post and read oceanographic messages of their choice. They will also have the option to browse the posted messages or subscribe to the BBS and have all the messages automatically sent to them through e-mail. Currently, NODC plans to have three different types of access to its Ocean BBS. The easiest way to browse and read messages will be to use Internet tools such as Mosaic or Gopher. The NODC Mosaic Home Page and Gopher server will also have utilities for posting user messages. Those who do not have Mosaic and/or Gopher servers at their disposal, can use e-mail to post, read, and subscribe to the BBS. New messages can be found in the main area of the BBS. Old messages will be combined and archived under a different heading on the BBS.

The initial NODC Ocean BBS has already been implemented, and improvements will be made when necessary. Instructions on how to use the new NODC Ocean Bulletin Board are as follows.

To Post Messages to the Bulletin Board

Using e-mail, the user simply sends the message to:

ocean_post@ocean.nodc.noaa.gov

Please use a subject heading, so that other users know the content of the message before they read it.

Example:

To: ocean_post@ocean.nodc.noaa.gov
From: <your e-mail address>
Subject: name of message, or your name
Body of Message:

Tools are being developed that will allow a user to post messages using Gopher and/or Mosaic. When they are complete, it will be announced on the Ocean Bulletin Board.

To Read Messages on the Bulletin Board

The user has three options:

1 - via Gopher: (must have gopher client software) gopher to —> gopher.nodc.noaa.gov and then select NODC's Ocean Bulletin Board and browse.

2 - via Mosaic: (must have Mosaic client software) Open URL —> http://www.nodc.noaa.gov/ (1) Select the Ocean Bulletin Board direct link; or (2) Select NODC's Gopher Server on the Home Page, and then select NODC's Ocean Bulletin Board and browse.

3 - via E-mail: Send a message to ocean_read@ocean.nodc.noaa.gov with no subject or message. You will receive via return mail a list of all NODC gopher offerings. Reply to the message and put an X in front of the line:

NODC's Ocean Bulletin Board

Then Send.

You will receive via return mail a list of all items on the bulletin board. Again, reply and insert an X in front of the items that you want to receive and send it. (NOTE: no X's will get you everything in the list). Keep doing this until you have seen everything that interests you.

To Subscribe to the Bulletin Board

Using this option, any messages posted to the Ocean Bulletin Board will automatically be sent to you through e-mail. The bulletin board works in concert with a list processor. To subscribe, send an e-mail message to:

listproc@gopher.nodc.noaa.gov

with the line —> subscribe ocean_list Your Name in the body of the message. No subject is needed on the subject line.

Example:

To: listproc@gopher.nodc.noaa.gov
From: jsmith@nodc.noaa.gov
Subject:
subscribe ocean_list John Smith

NOTE: To be removed from the list send the line: unsubscribe ocean_list Your Name

NODC Contact Information

National Oceanographic Data Center
NOAA/NESDIS E/OC21
User Services Branch
1825 Connecticut Ave. NW
Washington, DC 20235
Phone: (202) 606-4549
E-mail: services@nodc.noaa.gov

MeetingS Timetable - 1995

WOCE Meetings

February 21–23	US WOCE Atlantic Planning, Atlanta, Georgia
March 13–17	WCRP JSC-16, JPL, Pasadena
March 18–19	EXEC-10, JPL, Pasadena
April 24–27	DPC-8, Tallahassee, Florida
May 2–5	UOT-DAC QC Workshop, La Jolla, California
June	IWP-3, Paris

Science Meetings

February 7	The 5th IEEE Working Conference on Current Measurements, St Petersburg, Florida
March 13–17	WMO Symposium on Assimilation of Observations in Meterology and Oceanography, Tokyo
April 2–7	International TOGA Science Conference, Melbourne
April 3–7	European Geophysical Society XX General Assembly, Hamburg
May 29 – 2 June	29th Annual Congress of the Canadian Meteorological and Oceanographic Society, Kelowna, British Columbia
June 5–12	XVIII Pacific Science Congress, Peking
July 2–14	IUGG XXI General Assembly, Boulder, Colorado
September 4–8	3rd International Conference on Modelling of Global Climate Change and Variability, Hamburg
September 25–29	IGBP - Global Analysis Interpretation and Modelling, Garmisch

For more information on the above meetings contact the IPO.

If you are aware of any conferences or workshops which are suitable for the presentation of WOCE results and are not mentioned in the above list please let the IPO know.

WOCE is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of WOCE is under the guidance of the JSC Scientific Steering Group for WOCE, assisted by the WOCE International Project Office. JSC is the main body of WMO-ICSU-IOC, formulating overall WCRP scientific concepts.

The WOCE Newsletter is edited at the WOCE IPO at the Institute of Oceanographic Sciences Deacon Laboratory, Brook Road, Wormley, Godalming, Surrey, GU8 5UB, UK (Tel: 44-1428-684141, Fax: 44-1428-683066, e-mail: woceipo@unixa.nerc-wormley.ac.uk). Financial support is provided by the Natural Environment Research Council, UK.

Scientific material should not be used without agreement of the author.

We hope that colleagues will see this Newsletter as a means of reporting work in progress related to the Goals of WOCE as described in the Scientific Plan. The SSG will use it also to report progress of working groups, experiment design and models.

The editor will be pleased to send copies of the Newsletter to institutes and research scientists with an interest in WOCE or related research.